88-4202

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

HYDROGEOLOGY OF THE WESTERN PART OF THE SALT RIVER VALLEY AREA, MARICOPA COUNTY, ARIZONA

BY

JAMES G. BROWN AND D.R. POOL

U.S. GEOLOGICAL SURVEY
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PREPARED IN COOPERATION WITH THE
ARIZONA DEPARTMENT OF WATER RESOURCES,
SALT RIVER PROJECT, AND
ARIZONA MUNICIPAL WATER USERS' ASSOCIATION

BROWN AND POOL—HYDROGEOLOGY OF THE WESTERN PART OF THE SALT RIVER VALLEY AREA, ARIZONA

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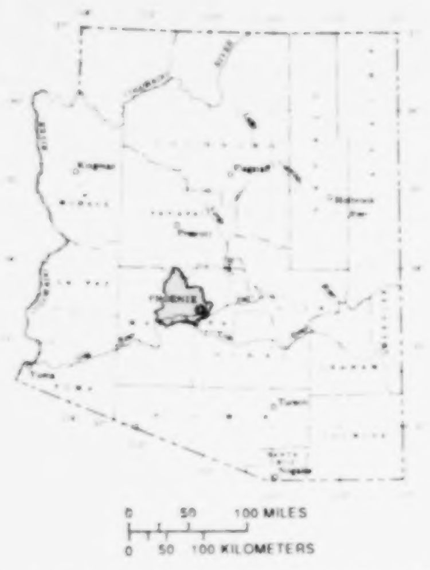

Figure 1.--Location of study area (shaded).

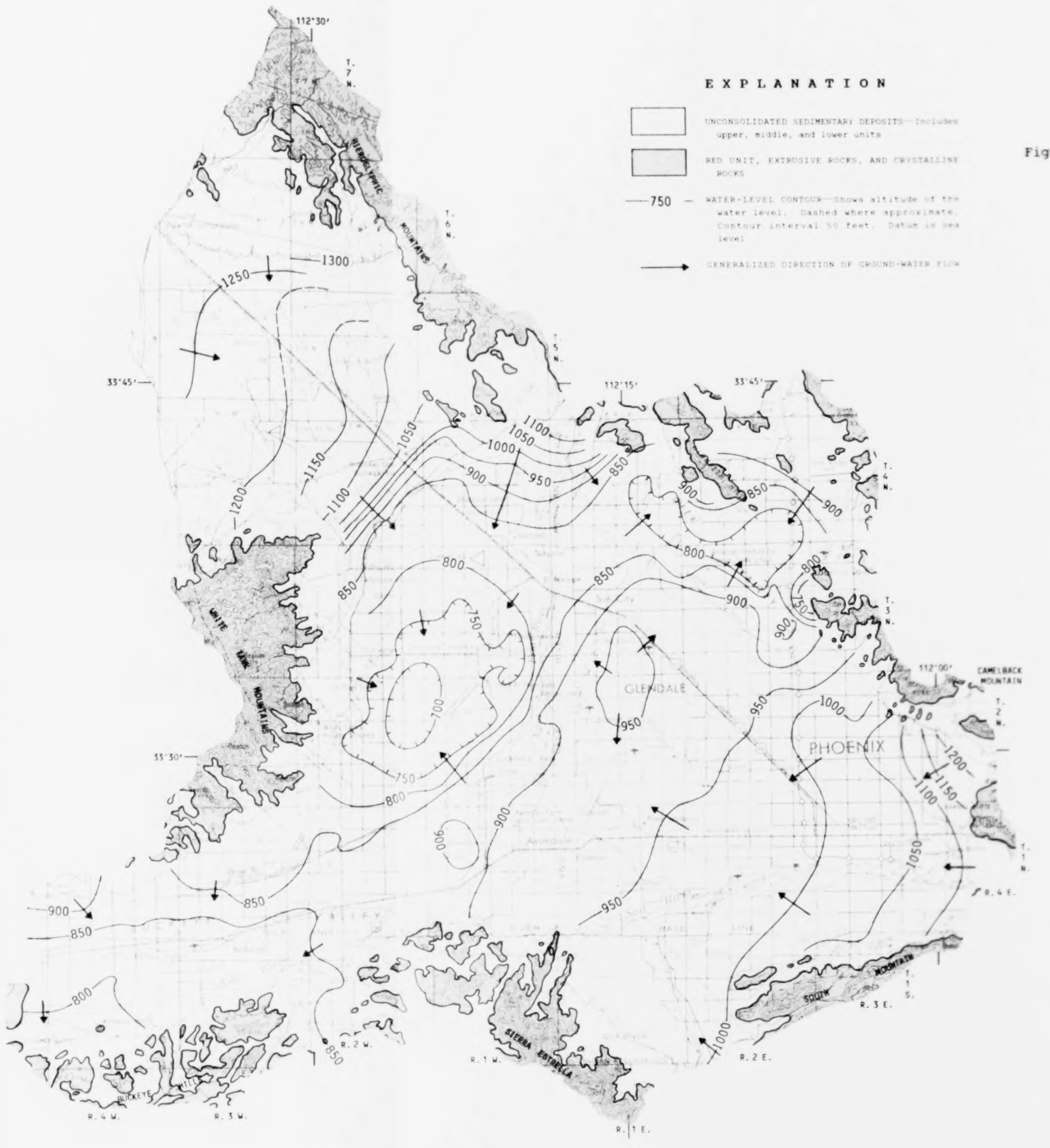
EXPLANATION
UNCONSOLIDATED SEDIMENTARY DEPOSITS—Includes upper, middle, and lower units
RED UNIT, EXTRUSIVE ROCKS, AND CRYSTALLINE ROCKS
—750— WATER-LEVEL CONTOUR—Shows altitude of the water level. Dashed where approximate. Contour interval 50 feet. Datum is sea level
GENERALIZED DIRECTION OF GROUND-WATER FLOW
112°30'
112°15'
112°00'
33°45'
33°30'
T. 7 N.
T. 6 N.
T. 5 N.
HIEROGLYPHIC MOUNTAINS
WHITE TANK MOUNTAINS
SIERRA ESTRELLA
CAMELBACK MOUNTAIN
GLENDALE
PHOENIX
1300
1250
1200
1150
1100
1050
1000
950
900
850
800
750
R. 4 W.
R. 3 W.
R. 1 E.
R. 2 E.
R. 3 E.
R. 4 E.

Figure 2.--Altitude of the water level, November 1984 to January 1985.

EXPLANATION

Qs UPPER UNIT—Gravel, sand, and silt

QTb BASALT—Basaltic flow rocks. May overlie middle unit

QTs MIDDLE UNIT—Silt, clay, siltstone, and silty sand and gravel. Overlain by the upper unit, which is shown on sections only

Ts Tsu Tsl Tb LOWER UNIT—Lower unit (Ts) consists of two parts. Younger and upper part (Tsu) is silt, clay, mudstone, siltstone, gypsiferous mudstone, gypsum, and sand and gravel. Older and lower part (Tsl) is mudstone, siltstone, gypsiferous and anhydritic mudstone, sand, gravel, conglomerate, halite, gypsum, and anhydrite. Crops out locally southwest of the Hedgpeth Hills and at the east edge of the study area. Overlain in most of the study area by the upper part of the lower unit, which is shown on sections only. Basalt (Tb) is interbedded with the older part of the unit, which is shown on sections only. Overlain by the middle unit

Tr Tv RED UNIT AND EXTRUSIVE ROCKS—Red unit (Tr) consists of breccia, conglomerate, sandstone and siltstone, and, in places, mafic to felsic flows and pyroclastic rocks in the upper part. Extrusive rocks (Tv) consist of rhyolitic to basaltic pyroclastic and flow rocks

TpЄg CRYSTALLINE ROCKS—Schist, gneiss, granite, quartzite, and metavolcanic rocks

GEOLOGIC CONTACT

U D CONCEALED FAULT—U, upthrown side; D, downthrown side; queried where uncertain

--500-- APPROXIMATE DEPTH BELOW LAND SURFACE TO TOP OF CRYSTALLINE ROCKS—Locally may be to top of extrusive rocks

—20— LINE OF EQUAL GRAVITY—Interval 5 milligals

SELECTED POTASSIUM-ARGON ROCK AGES IN SOUTHERN ARIZONA

[M.Y., million years ago]

Qs
- 3.3 M.Y. (MEAN OF MULTIPLE SAMPLES)—Gil flow overlying second highest of thr along the Gila River near Gillespie 40 miles southwest of Phoenix (8, 9)

QTs
- 8.12 ± 0.64 M.Y.—Basalt, interbedded wit conglomerate at Poston Butte, 2 miles n Florence (7)

Tsu Tsl Tb
- 8.87 ± 0.26 M.Y.—Basalt, displaced 10 to high-angle fault; overlies fine-graine sediments; overlain by Gila River gr 4 miles east of Florence (7)
- 10.52 ± 0.61 M.Y.—Basalt near top of th sequence, in drill hole about 1,030 fe surface in western part of Salt River V 1 mile east of Luke Air Force Base (7)
- 15.8 ± 0.34 M.Y.—Trachyte, 9,060 feet surface in drill hole near Eloy, 740 feet of conglomerate, which is 6,000 feet of anhydrite (6)
- 16.63 ± 0.35 M.Y.—Basalt from eastwa basalt-tuff-mudstone terrain west of (5)

Tr Tv
- 17.56 ± 0.37 M.Y.—Basaltic andesite, grained beds of red unit on Tempe Butte
- 17.71 ± 0.43 M.Y.—Rhyolitic ash fl McDowell; overlies red beds (7)
- 18.01 ± 0.43 M.Y.—Trachyte breccia about 900 feet of red conglomerate at M near Granite Reef Dam (7)
- 18.40 ± 0.50 M.Y.—Dacite, top of Picketp near Superior (7)
- 18.70 ± 0.44 M.Y.—Trachyte boulder in te McDowell (7)
- 19.2 ± 0.47 M.Y.—Basalt, lowermost flow of Lookout Mountain (7)
- 19.40 ± 0.47 M.Y.—Poorly welded pyroclas drill hole, sec. 1, T. 2 S., R. 6 E 7,938 feet below land surface (7)
- 20.68 ± 0.82 M.Y.—Dacite, Superstition M
- 20.7 ± 0.5 M.Y.—Basalt at 1,000 to 1,200 land surface interbedded with red f sediments in drill hole, sec. 24, T. 1 (11)
- 22 ± 1.2 M.Y.—Basaltic andesite overlyin about 4,730 feet below land surface in sec. 8, T. 4 N., R. 4 E. (5, 10)
- 22.65 ± 0.54 M.Y.—Trachyte, overlies re hole in sec. 8, T. 4 N., R. 4 E. (7)
- 23.0 ± 0.5 M.Y.—Mafic volcanic rock salt body at 820 to 840 feet below lan drill hole, sec. 9, T. 2 N., R. 1 W. (1
- 24.4 ± 2.6 M.Y.—Andesite porphyry Formation, Davidson Canyon, east of Tu
- 26.3 ± 0.8 M.Y.—Andesite porphyry over Conglomerate southwest of Tucson (4)
- 27.9 ± 2.6 M.Y.—Tuff from Helmet Fa Sierrita Mountains, southwest of Tucson
- 28.0 ± 2.6 M.Y.—Andesite porphyry on Do near Tucson (2)
- 38.5 ± 1.3 M.Y.—Rhyolite at base of Red near Tucson (2)
- 39.4 ± 0.9 M.Y.—Basaltic andesite in sec. 1, T. 2 S., R. 6 E., 8,922 to 8,9 land surface (7)

SOURCES OF DATA

(1) Bikerman and Damon, 196
(2) Damon and Bikerman, 196
(3) Finnell, 1970
(4) Percious, 1968
(5) Scarborough and Wilt, 197
(6) Shafiqullah and others, 19
(7) Shafiqullah and others, 19
(8) Lee and Bell, 1975
(9) Euge and others, 1978
(10) Eberly and Stanley, 197
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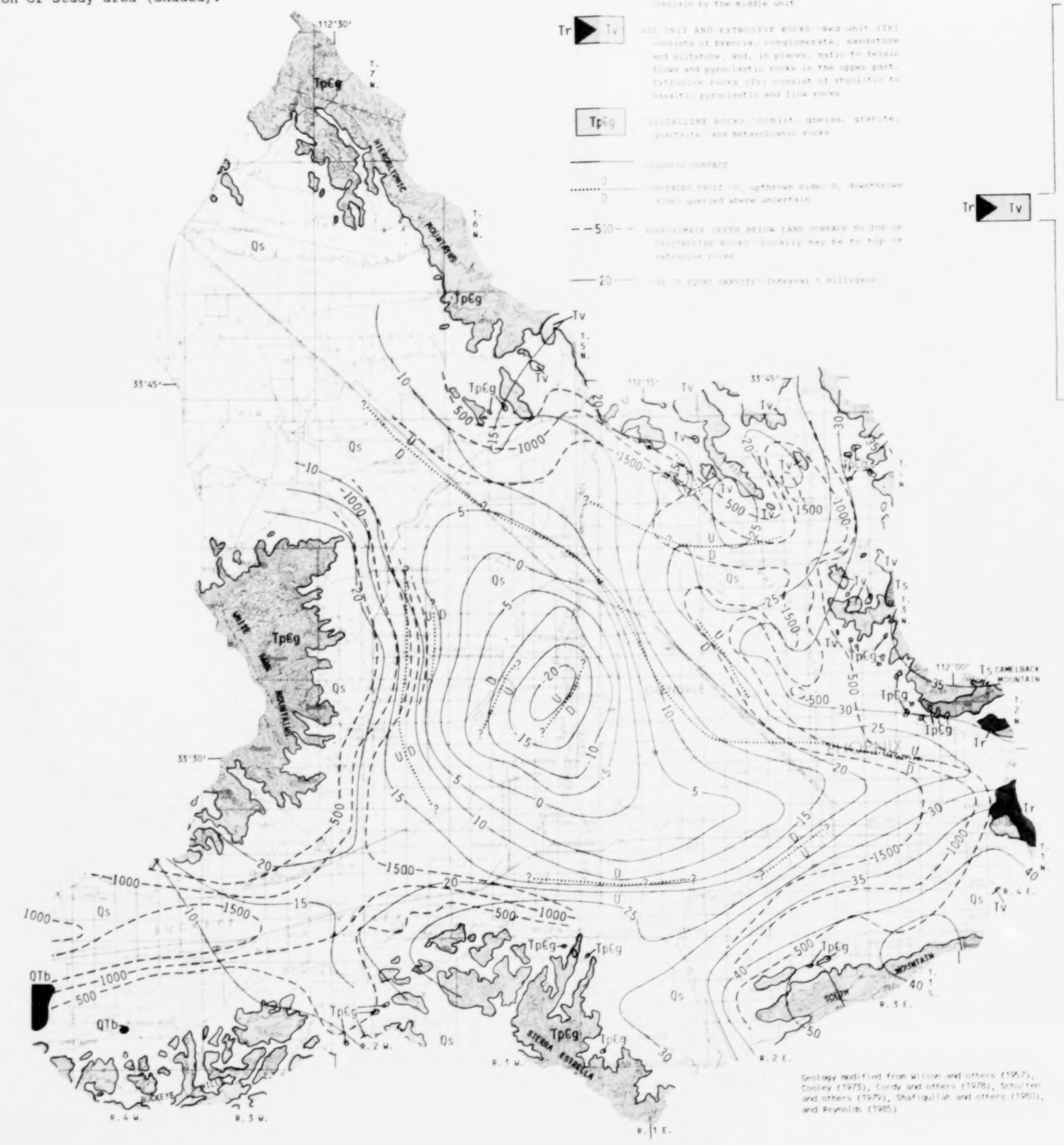

Geology modified from Wilson and others (1957), Cooley (1973), Cordy and others (1978), Schulten and others (1979), Shafiqullah and others (1980), and Reynolds (1985)

Figure 3.--Generalized geology, residual gravity, and depth to the top of crystalline and extrusive rocks.

INTRODUCTION

The Salt River Valley is a major population and agricultural center of more than 3,000 mi² in central Arizona (fig. 1). The western part of the Salt River Valley area (area of this report) covers about 1,500 mi². The Phoenix metropolitan area with a population of more than 1.6 million in 1985 (Valley National Bank, 1987) is located within the valley. The watersheds of the Salt, Verde, and Agua Fria Rivers provide the valley with a reliable but limited surface-water supply that must be augmented with ground water even in years of plentiful rainfall. Large-scale ground-water withdrawals began in the Salt River Valley in the early part of the 20th century; between 1915 and 1983, the total estimated ground-water pumpage was 81 million acre-ft (U.S. Geological Survey, 1984). Because of the low average annual rainfall and high potential evapotranspiration, the principal sources of ground-water recharge are urban runoff, excess irrigation, canal seepage, and surface-water flows during years of higher-than-normal rainfall. Withdrawals greatly exceed recharge and, in some areas, ground-water levels have declined as much as 350 ft (Laney and others, 1978; Ross, 1978).

In the study area, ground-water declines of more than 300 ft have occurred in Deer Valley and from Luke Air Force Base north to Beardsley. As a result, a large depression of the water table has developed west of Luke Air Force Base (fig. 2). Ground-water use has decreased in recent years because precipitation and surface-water supplies have been greater than normal. Increased precipitation also caused large quantities of runoff to be released into the normally dry Salt and Gila River channels. From February 1978 to June 1980, streamflow losses of at least 90,000 acre-ft occurred between Jointhead Dam near the east boundary of the study area and Gillespie Dam several miles southwest of the west edge of the study area (Mann and Rhone, 1983). Consequently, ground-water declines in a large part of the basin have slowed, and ground-water levels in some areas have risen significantly. In many areas along the Salt River and northeast of the confluence of the Salt and Agua Fria Rivers, ground-water levels rose more than 25 ft between 1978 and 1984 (Reeter and Remick, 1986).

Purpose and Scope

The purpose of this investigation was to develop a better understanding of the hydrogeologic framework of the aquifer underlying the western part of the Salt River Valley. This report describes the lithologic, hydraulic, and water-quality characteristics of the hydrogeologic units that make up the basin-fill aquifer. The hydrogeology of the eastern part of the Salt River Valley is described by Laney and Hahn (1986).

Acknowledgments

The authors would like to thank the employees of Phoenix, Glendale, Sun City, and other towns who supplied well, water-quality, and lithologic data. The Arizona Bureau of Geology and Mineral Technology provided assistance and a workspace in which to examine well cuttings. The Basic Data Unit of the Arizona Department of Water Resources provided a current data base of well information. Private consultants who provided

significantly higher in the surrounding mountains. Average annual rainfall is about 9.5 in. at Lake Pleasant, about 10 mi north of Sun City and 11 in. at Cave Creek, which is 10 mi northeast of the study area (Sellers and others, 1985). Most of the precipitation occurs during two rainy seasons. During the winter, occasional storm systems move inland from the Pacific Ocean and result in rains that generally are widespread and light to moderate in intensity. During the summer, rain results from moist air masses moving northward from the Gulf of Mexico and the west coast of Mexico. Summer rains are more localized than winter rains and may vary greatly in intensity. The average annual pan evaporation measured a few miles east of the study area in Tempe was 72 in. for 1969-73 (Sellers and Hill, 1974, p. 44). Potential evapotranspiration may equal pan evaporation and therefore may be about 10 times the average annual rainfall.

The Salt, Gila, and Agua Fria Rivers are the main streams in the western part of the Salt River Valley area. Most of the low flow in these rivers is sewage effluent and irrigation return flow. High flows occur during or following periods of intense or prolonged rainfall when large amounts of water are released from upstream reservoirs into the normally dry river channels. The Salt River enters the study area at Tempe and flows into the Gila River about 15 mi southwest of downtown Phoenix. The Gila River enters the study area through the gap between Sierra Estrella and South Mountain and flows to the extreme west boundary of the study area about 8 mi west of Buckeye. The Agua Fria River enters the valley from the Hieroglyphic Mountains, flows south, and joins the Gila River several miles south of Avondale. Flow in these three rivers originates outside the study area.

Most of the smaller streams, including the New River, Waterman Wash, and Skunk Creek, are dry most of the time and flow only during and after intense or prolonged rains. The New River and its main tributary, Skunk Creek, enter the valley from the north and flow into the Agua Fria River southwest of Glendale. Waterman Wash flows northward into the Gila River several miles east of Buckeye.

Methods of Investigation

Available lithologic, geophysical, particle-size, aquifer-test, specific-capacity, specific-yield, and water-quality data were inventoried and compiled to provide a complete data base. Well drilling was monitored during 1981-85 to obtain drill cuttings in data-deficient areas. In addition, drill cuttings from more than 110 wells drilled over the last 40 years were inspected at the office of the Arizona Bureau of Geology and Mineral Technology in Tucson. These samples aided in defining the lithologic character of the basin-fill deposits. Aquifer tests were done at 23 existing large-capacity wells from May 1984 to September 1985. Tests were limited mostly to wells that were perforated in a single hydrogeologic unit in order to provide transmissivity, storage-coefficient, and hydraulic-conductivity data for individual units.

Water-quality samples were collected at 56 sites during the summers of 1984 and 1985 to augment the existing data base. Samples were taken only from wells in which the depth and

Structure

The occurrence and movement of ground water in the study area are controlled partly by the structure of the crystalline and the sedimentary rocks. The crystalline rocks delineate the areal and vertical extent of the aquifer. Primary hydraulic properties of the aquifer are influenced by the thickness, areal distribution, and tilting of the sedimentary units. Faulting and fracturing may form barriers to ground-water flow or provide avenues of increased permeability.

The study area is divided into northeast and southwest regions by a major structure that extends from Wittman in the northwest corner of the basin to Papago Buttes in the southeast corner. This structure, which probably is a major fault within the crystalline rocks, is defined by steep gravity gradients and the pronounced gravity low that is southwest of the structure (fig. 3).

The northeast region is dominated by several structural blocks of crystalline rocks that are oriented in a northwest direction and slightly tilted to the northeast. The predominant stratigraphic sequence of each block consists of middle to upper Tertiary volcanic rocks overlying Precambrian schist and granite. Structurally high surfaces of crystalline rock occur at the southwest edge of each block. Structural lows and large basin-fill thicknesses occur at the northeast edge of each block. The most pronounced of these blocks is indicated by a buried northwest-trending structural high near Glendale. Gravity data and several drillers' logs indicate that crystalline rocks are at shallow depths and the thickness of the basin fill increases to the northeast.

The crystalline rocks in the southwest region consist mainly of Tertiary gneiss and granite and Precambrian granite. In this region, South Mountain, the White Tank Mountains, and Sierra Estrella may lie within separate structural blocks, as indicated by steep gravity gradients between the mountains. South Mountain is a northeast-trending arch structure. The northwest limb of the arch dips basinward at less than 10°, and the nose plunges beneath basin fill at dips of 10° to 15° (Reynolds, 1985). The arch is overlain by a detachment fault and highly faulted and tilted middle to upper Tertiary rocks including the red unit. Similar arch structures are not known to exist in the White Tank Mountains or Sierra Estrella.

A large structural depression that forms the down-faulted core of the basin is well defined by an extensive gravity low in the southwest region (fig. 3). Steep gravity gradients, which probably represent steep-angle normal faults, bound the depression on three sides—northeast, west, and south—forming a graben. The graben is roughly triangular in shape and includes the area of Luke Air Force Base, the Luke salt body (Eaton and others, 1972) in the center of the gravity low, and the east- and west-trending region of low-gravity values from Tolleson to Phoenix.

The characteristics of the basin-fill aquifer vary between the northeast and southwest regions. The northeast region contains basin fill that generally is less than 2,000 ft thick. The lower unit of the basin fill is the main water-bearing unit in the northeast region because the overlying units generally are thin and depths to water are great. (fig. 3). Metamorphic and granitic rocks have been penetrated by wells near the edge of the basin. The rocks form a virtually impermeable boundary at the basin margins and beneath the basin fill.

Extrusive Rocks

Extrusive rocks are volcanic rocks that include rhyolitic to basaltic rocks of middle to late Tertiary age and basalt flows of middle Tertiary to Quaternary age (Wilson and others, 1957). Most of the volcanic rocks are of minor hydrologic significance; however, some of the rocks may contain permeable zones where they are highly vesicular or fractured.

Volcanic rocks older than middle Miocene age are exposed in the Phoenix and Hieroglyphic Mountains (Wilson and others, 1957) and are commonly encountered by wells in the north and northeast parts of the study area. Younger basalt flows of middle Miocene age are intercalated with sediments that probably are equivalent to the lower unit of basin fill north of the study area (fig. 3) (Scarborough and Wilt, 1979). Younger mafic volcanic units of late Miocene age have been encountered at depth by well drilling near the center of the basin. Basalts of late Tertiary and Quaternary age are interbedded with basin sediments in the extreme southwestern part.

Sedimentary Rocks

Red Unit

The red unit is present mainly in the southeastern part of the study area and is not a significant source of water. The red unit, described by Cooley in Arteaga and others (1968), consists of reddish-colored, well-cemented breccia, conglomerate, sandstone, and siltstone and contains granitic and rhyolitic detritus. The size of the particles in the breccia and conglomerate range from clay to boulders as large as 15 ft in diameter. Bedding generally is poorly defined, and a large part of the unit probably is debris flows. Siltstone and sandstone deposits generally are better stratified and sorted than the coarse-grained deposits and, in places, are interbedded with poorly sorted breccia and conglomerate. Locally, mafic to felsic flow rocks and some pyroclastic rocks are interbedded with the sedimentary rocks at the top of the unit.

The red unit was deposited prior to high-angle normal faulting and formation of the late Tertiary sedimentary basins. Most of the unit has been tilted 20 to 45 degrees by earlier structural events (Laney and Hahn, 1986). Age determinations of volcanic flows within the red unit range from about 17.5 to 22 m.y. (Laney and Hahn, 1986). Volcanic rocks in the upper part of the red unit have been dated at about 17.5 m.y. near Tempe Butte and about 18 to 18.5 m.y. near Mount McDowell. About 2,400 ft of red beds in a drill hole near Higley in the eastern part of the Salt River Valley area, about 20 mi southeast of the study area, are younger than about 19 m.y. Red beds in a drill hole in Paradise Valley a few miles east of the study area are older than 22 m.y.

Several wells encounter the red unit in the southeastern lower part is more consolidated and more homogeneous in terms of clast type and stratigraphy than the upper part. Evaporite deposits in the lower part generally are massive and consist of anhydrite, gypsum, and halite. Gypsum is the only evaporite found in the upper part and occurs as interbedded layers or is finely disseminated within the sediments. Lateral changes in stratigraphic facies and in thickness of both parts of the unit are associated with basin structures. Some of the lateral changes represent discontinuities that have been caused by faulting, especially in the lower part.

The lower part of the lower unit is moderately to well-cemented mudstone, siltstone, gypsiferous and anhydritic mudstone, sand, gravel, conglomerate, halite, gypsum, and anhydrite and includes basalt flows. The lower part is as much as 1,000 ft thick near the basin margins and may be more than 10,000 ft thick in the graben. The Luke salt body is an evaporite facies of the lower part. The base of the unit may contain several hundred feet of sand and gravel or conglomerate at the basin margins. The lower part includes fanglomerates, mudstones, and intercalated basalts, andesitic basalts, and tuffs of middle Miocene age that are exposed in the Hieroglyphic Mountains and found in the northern and northeastern parts of the basin.

Much of the lower part of the lower unit probably was deposited prior to 10 m.y. ago on the basis of the age of drill cuttings from a basalt within a gypsum and anhydrite sequence near the top of the unit (Peirce, 1973, 1976; Eaton and others, 1972). The lower part of the unit correlates, at least in part, with a similarly defined unit in the eastern part of the Salt River Valley area (Laney and Hahn, 1986), the lower unit described by Arteaga and others (1968), the deformed gravel of Davidson (1961) and Cooley and Davidson (1963), the Tinaja beds (Cooper, 1960; Davidson, 1973), and some of the middle fine-grained unit and the lower conglomerate unit described by the U.S. Bureau of Reclamation (1977).

A transition from the red unit to the lower unit of the basin fill and some low-angle faulting of the lower unit is indicated by the age and tilting of the lower unit at several locations. Tilted tuff, mudstone, and basalt dated at 16.6 m.y. occur west of Lake Pleasant (Scarborough and Wilt, 1979) and are equivalent to the lower unit. Core data from U.S. Bureau of Reclamation test well (B-01-01)12dda indicate that the fine-grained lower unit is tilted 20 to 45 degrees below a depth of 1,965 ft. In well (B-01-01)25bbb, the lower unit consists of red sediments with calcite and salty water. Red sediments and gypsum in well (A-01-01)13dbb are tilted 45 degrees and interpreted as red unit; however, the lithologic description is similar to that of the lower part of the lower unit. Age dating of drill cuttings from a mafic volcanic unit within the lower unit at well (B-02-01)09bdd indicated an age of 23 m.y. The volcanic unit was encountered at depths of 800 to 850 ft in a moderately fine-grained sequence of the lower part of the lower unit. The presence of salty water beneath the volcanic unit and high electrical resistivities below a depth of 900 ft indicate the presence of halite, although no halite was recovered in drill cuttings.

Average particle size in the lower part of the lower unit ranges from less than 20 to more than 80 percent sand and during deposition of the upper part of the lower unit and resulted in the deposition of fine-grained material(s) southwest and southeast of the salt body.

Deposits containing more than 80 percent sand and gravel occur in the south half of T. 1 N., R. 1 W., and the north half of T. 1 S., R. 1 W., and become finer to the east and west. This area of coarse material coincides with an area of high gravity values that delineate a shallow part of the basin in the Buckeye Valley (fig. 3). Deposits containing more than 60 percent sand and gravel also occur in the Sun City area. This coarse-grained material is associated with alluvial-fan deposits from the Agua Fria River and New River drainages. The unit becomes finer grained south of the major northwest-trending structure in the basin.

Thickness of the upper part of the lower unit is controlled by basin structure, subsidence, and locally by the Luke salt body. The unit is more than 1,000 ft thick in a trough that trends north and south along the west side of the basin between the Luke salt body and the White Tank Mountains. The unit is less than 100 ft thick in Buckeye Valley (fig. 8) and is absent along the mountain fronts in some areas.

The basin was closed and subsiding during the deposition of the lower unit on the basis of the following observations: (1) Fine-grained basin-center deposits of mudstone, silt, clay, and evaporites are dominant within the graben structure (fig. 6); (2) structural contours of the base of the upper part of the lower unit coincide closely with gravity contours; and (3) abrupt lateral changes in lithology increase with depth in the unit.

The upper part of the lower unit is fully saturated in most of the basin. Minor amounts of dewatering have occurred east of the White Tank Mountains and to a lesser extent in small areas south of Luke Air Force Base and in Deer Valley.

Middle Unit

The middle unit of the basin fill includes playa, alluvial-fan, and fluvial deposits of silt, clay, siltstone, and silty sand and gravel (figs. 6A-E). Most of the unit is weakly consolidated, but moderately to well-cemented siltstone occurs locally. Calcium carbonate cement is common. Generally, grain size decreases downward in the middle unit. Depth to the base of the middle unit ranges from zero near the mountains to about 800 ft west of Luke Air Force Base and south of Glendale. The thickest parts of the unit are in the central areas of the valley near gravity lows (fig. 3). The thickness of the middle unit is related to and controlled by basin structure and subsidence as well as by a structural low at the Luke salt body.

The distribution of fine-grained sediments in the middle unit is much less extensive and irregular than in the lower unit. The unit contains more than 40 percent sand and gravel throughout most of the basin (fig. 9). The fine-grained parts of the middle unit are localized, and the locations appear to be highly influenced by the large influx of sediment from the major drainages. Local fine-grained zones of less than 25 percent sand and gravel are present near Glendale and Goodyear. The drainage basins of the Agua Fria, Salt, and

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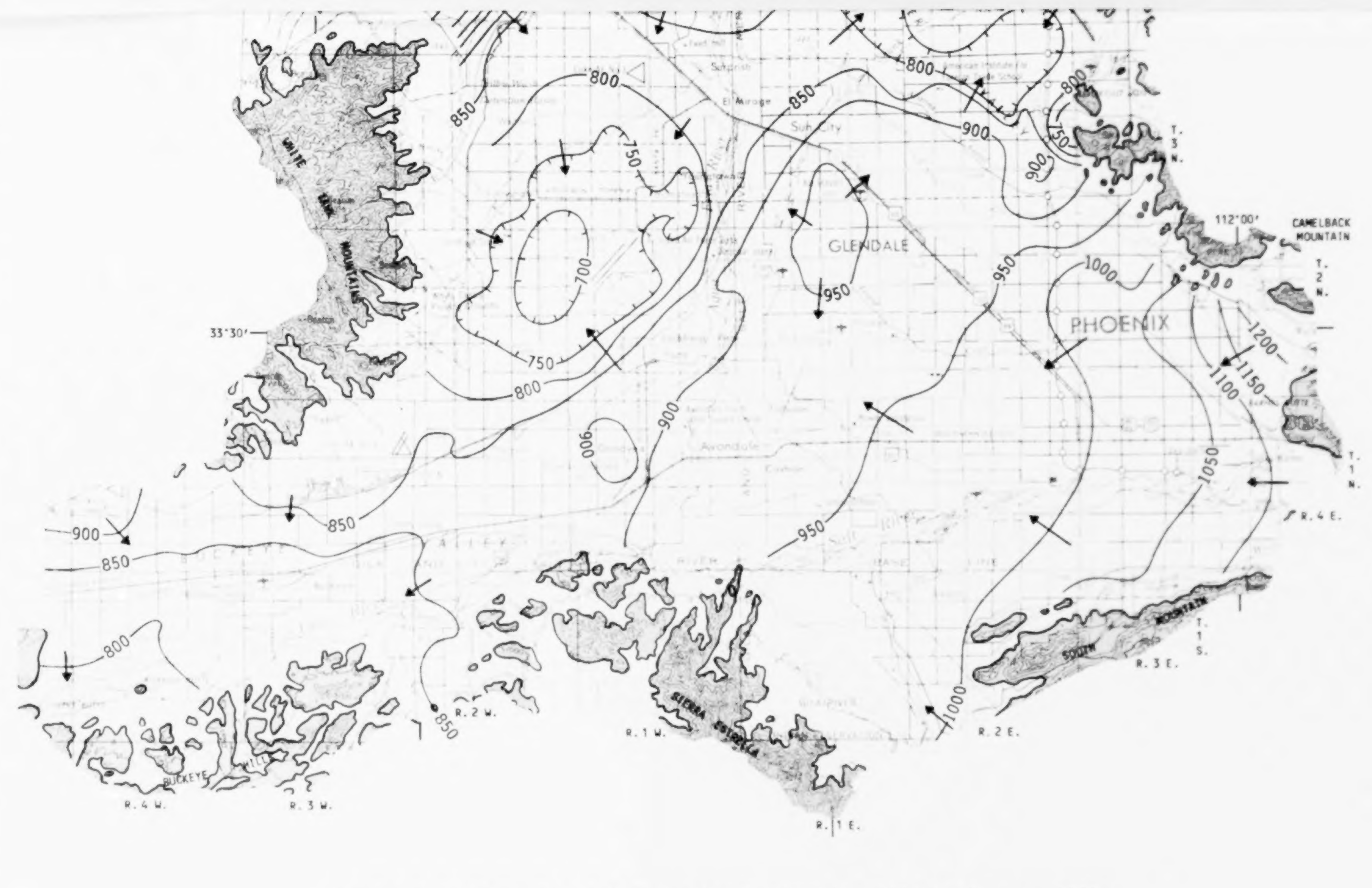
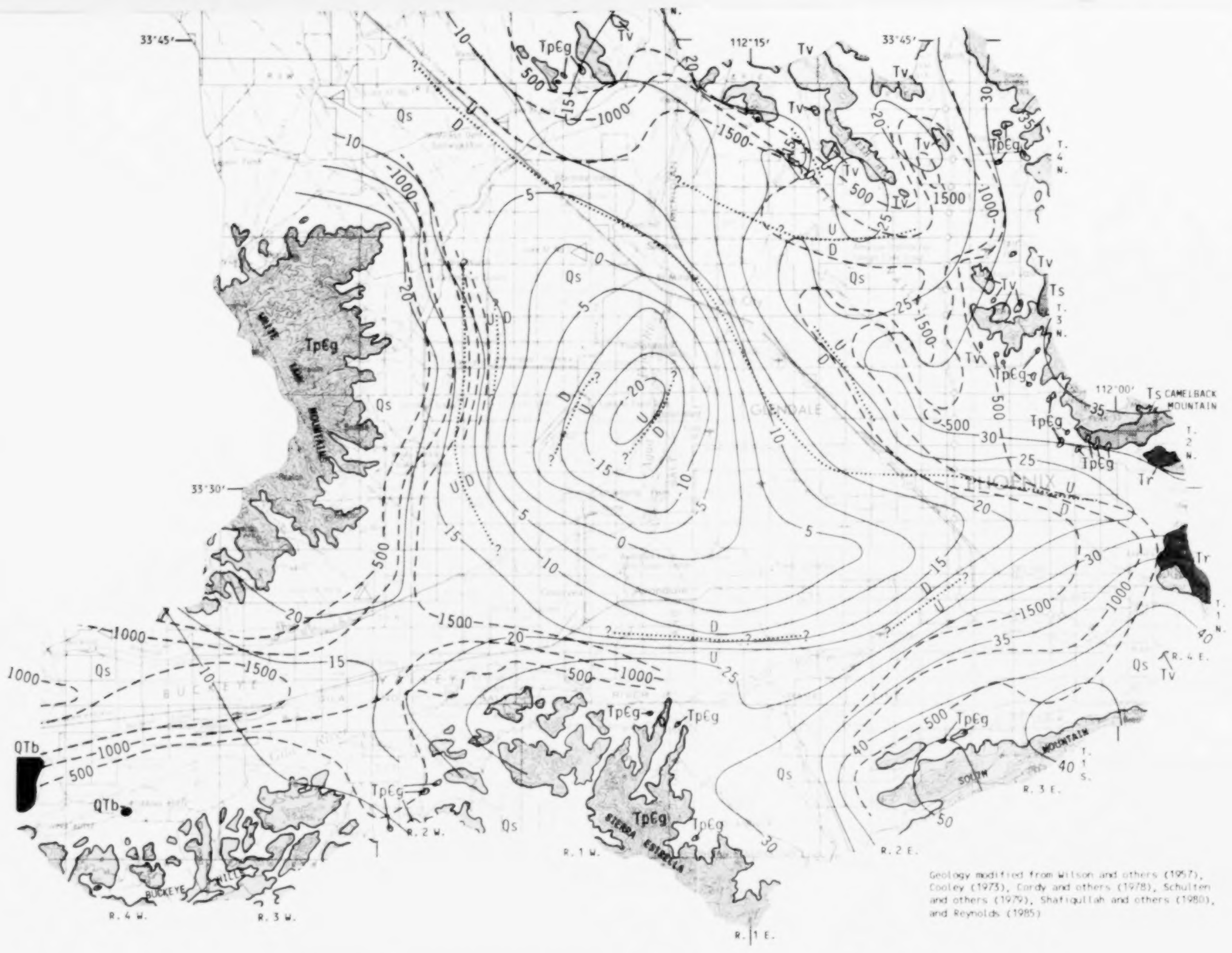


Figure 2.--Altitude of the water level, November 1984 to January 1985.



Geology modified from Wilson and others (1957), Cooley (1973), Cordy and others (1978), Schulten and others (1979), Shafiqullah and others (1980), and Reynolds (1985)

Figure 3.--Generalized geology, residual gravity, and depth to the top of crystalline and extrusive rocks.

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INTRODUCTION

The Salt River Valley is a major population and agricultural center of more than 3,000 mi² in central Arizona (fig. 1). The western part of the Salt River Valley area (area of this report) covers about 1,500 mi². The Phoenix metropolitan area with a population of more than 1.8 million in 1985 (Valley National Bank, 1987) is located within the valley. The watersheds of the Salt, Verde, and Agua Fria Rivers provide the valley with a reliable but limited surface-water supply that must be augmented with ground water even in years of plentiful rainfall. Large-scale ground-water withdrawals began in the Salt River Valley in the early part of the 20th century; between 1915 and 1983, the total estimated ground-water pumpage was [illegible] million acre-ft (U.S. Geological Survey, 1984). Because of the low average annual rainfall and high potential evapotranspiration, the principal sources of ground-water recharge are urban runoff, excess irrigation, canal seepage, and surface-water flows during years of higher-than-normal rainfall. Withdrawals greatly exceed recharge and, in some areas, ground-water levels have declined as much as [illegible] ft (Laney and others, 1978; Reeter, 1984).

In the study area, ground-water declines of more than [illegible] ft have occurred in Deer Valley and from Luke Air Force Base north to Beardsley. As a result, a large depression of the water table has developed west of Luke Air Force Base (fig. 2). Ground-water use has decreased in recent years because precipitation and surface-water supplies have been greater than normal. Increased precipitation also caused large quantities of runoff to be released into the normally dry Salt and Gila River channels. From February 1978 to June 1980, [illegible] occurred between [illegible] near the east boundary of the study area and [illegible] several miles southeast of the west edge of the study area [illegible]. Consequently, ground-water declines in a large part of the basin have slowed, and ground-water levels in some areas have risen significantly. In many areas along the Salt River and northeast of the confluence of the Salt and Agua Fria Rivers, ground-water levels rose more than [illegible] ft between [illegible] and [illegible] (Reeter and [illegible]).

Purpose and Scope

The purpose of this investigation was to develop a better understanding of the hydrogeologic framework of the aquifer underlying the western part of the Salt River Valley. This report describes the lithologic, hydraulic, and water-quality characteristics of the hydrogeologic units that make up the basin-fill aquifer. The hydrogeology of the eastern part of the Salt River Valley is described by Laney and Hahn (1986).

Acknowledgments

The authors would like to thank the employees of Phoenix, [illegible]

Physical Setting

[illegible]

The western part of the Salt River Valley area lies in the northeastern part of the Sonoran desert and has hot summers and cool winters. The average maximum daily temperature in July is 105° F; the average minimum is [illegible]° F. The average maximum and minimum daily temperatures in December are [illegible] and [illegible]° F, respectively (Sellers and others, [illegible]). Average rainfall on the valley floor is about 7.5 [illegible]

[illegible]

Methods of Investigation

[illegible]

HYDROGEOLOGY

[illegible]

Structure

[illegible]

Crystalline Rocks

[illegible]

Extrusive Rocks

[illegible]

Sedimentary Rocks

Red Unit

[illegible]

Lower Unit

[illegible] lower part is more consolidated and more homogeneous in terms of clast type and stratigraphy than the upper part. Evaporite deposits in the lower part generally are massive and consist of anhydrite, gypsum, and halite. Gypsum is the only evaporite found in the upper part and occurs as interbedded layers or is finely disseminated within the sediments. Lateral changes in stratigraphic facies and in thickness of both parts of the unit are associated with basin structures. [illegible]

[illegible] unit in the southeastern part of the basin and [illegible] with detritus of the red unit. Calcium [illegible] form cement that reduces the porosity of some of [illegible] grained deposits.

[illegible] unit is divided into lower and upper parts. Both [illegible] generally fine grained but differ in consolidation, types of evaporite deposits, and structure. The [illegible]

[illegible] deposits are found in the deepest part of the basin. [illegible] of the Luke salt body apparently has had a [illegible] distribution of particle size in the upper part of the lower unit. Deposits over the salt body [illegible] percent sand and gravel. These deposits are surrounded on the west, south, and east by a zone of [illegible] containing from 15 to 35 percent sand and gravel. This pattern suggests that doming of the salt body [illegible]

during deposition of the upper part of the lower unit and resulted in the deposition of fine-grained materials southwest and southeast of the salt body.

Deposits containing more than 80 percent sand and gravel occur in the south half of T. 1 N., R. 1 W., and the north half of T. 1 S., R. 1 W., and become finer to the east and west. This area of coarse material coincides with an area of [illegible]

Middle Unit

[illegible]

Clast types could be used to distinguish the middle and lower units in places. Near Luke Air Force Base, the middle unit contains a larger amount of several types of volcanic clasts. South of Glendale near the Salt River, rounded quartzite gravel and intervals of well-sorted sand occur near the top of the middle unit. In most areas, the clasts in the lower unit are more monolithologic than those in the middle unit.

[illegible]

Base from U.S. Geological Survey 1:250,000
Mesa, 1954-69 and
Phoenix, 1954-69

5 0 5 10 MILES
5 0 5 10 KILOMETERS

TOPOGRAPHIC CONTOUR INTERVAL 200 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

HYDROGEOLOGY OF THE WESTERN PART OF THE SALT RIVER VALLEY AREA, MARICOPA COUNTY, ARIZONA

By James G. Brown and D. R. Pool
1989

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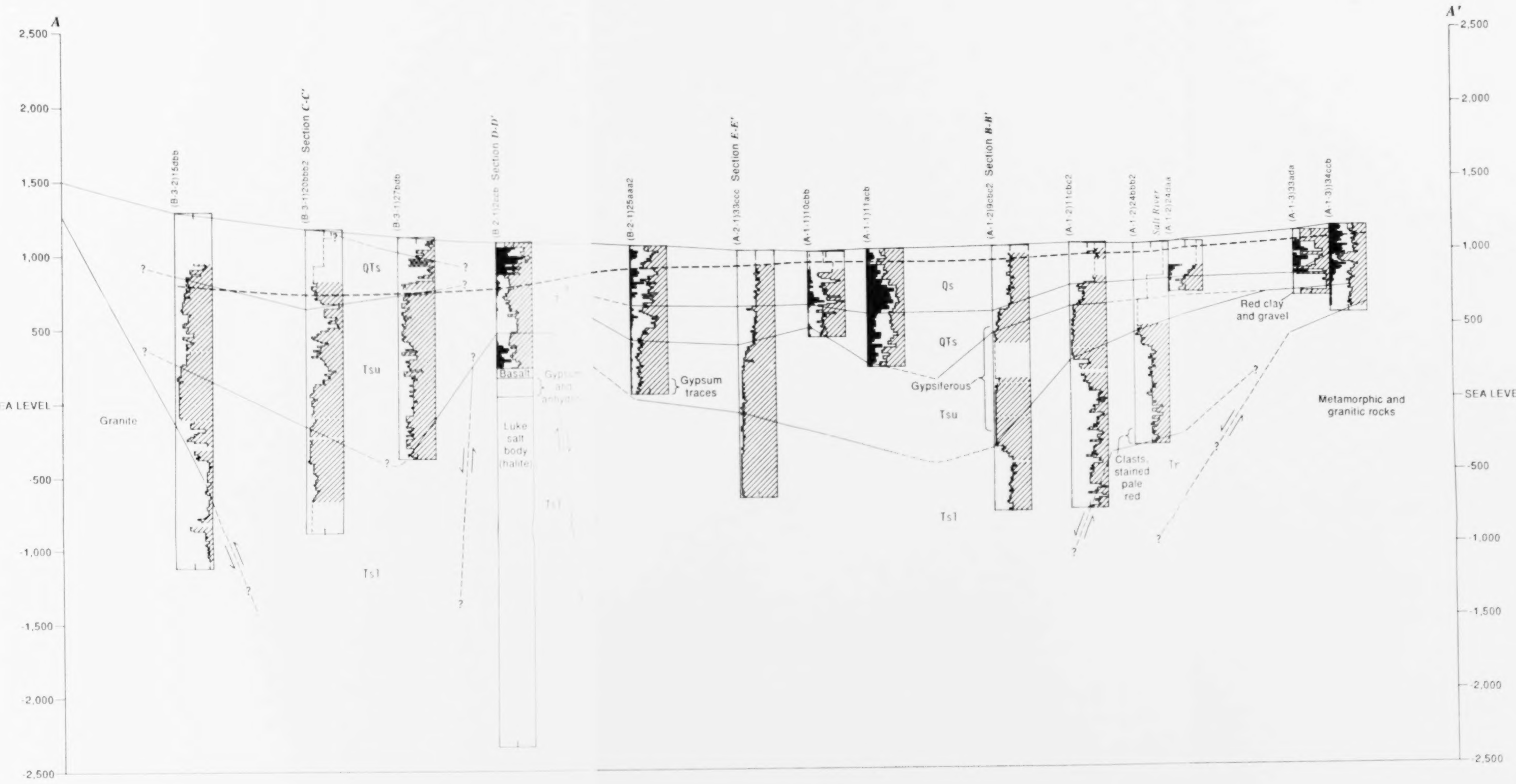


EXPLANATION

For description of rock units, see figure 3, sheet 1. Geology on sections is generalized

———?— — GEOLOGIC CONTACT—Dashed where approximately located; queried where uncertain

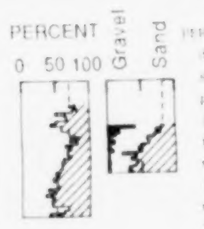
⇄?— — FAULT—Dashed where approximately located; queried where uncertain. Arrows show relative movement

—≀≀— Indicates where horizontal spacing is increased to show data more clearly

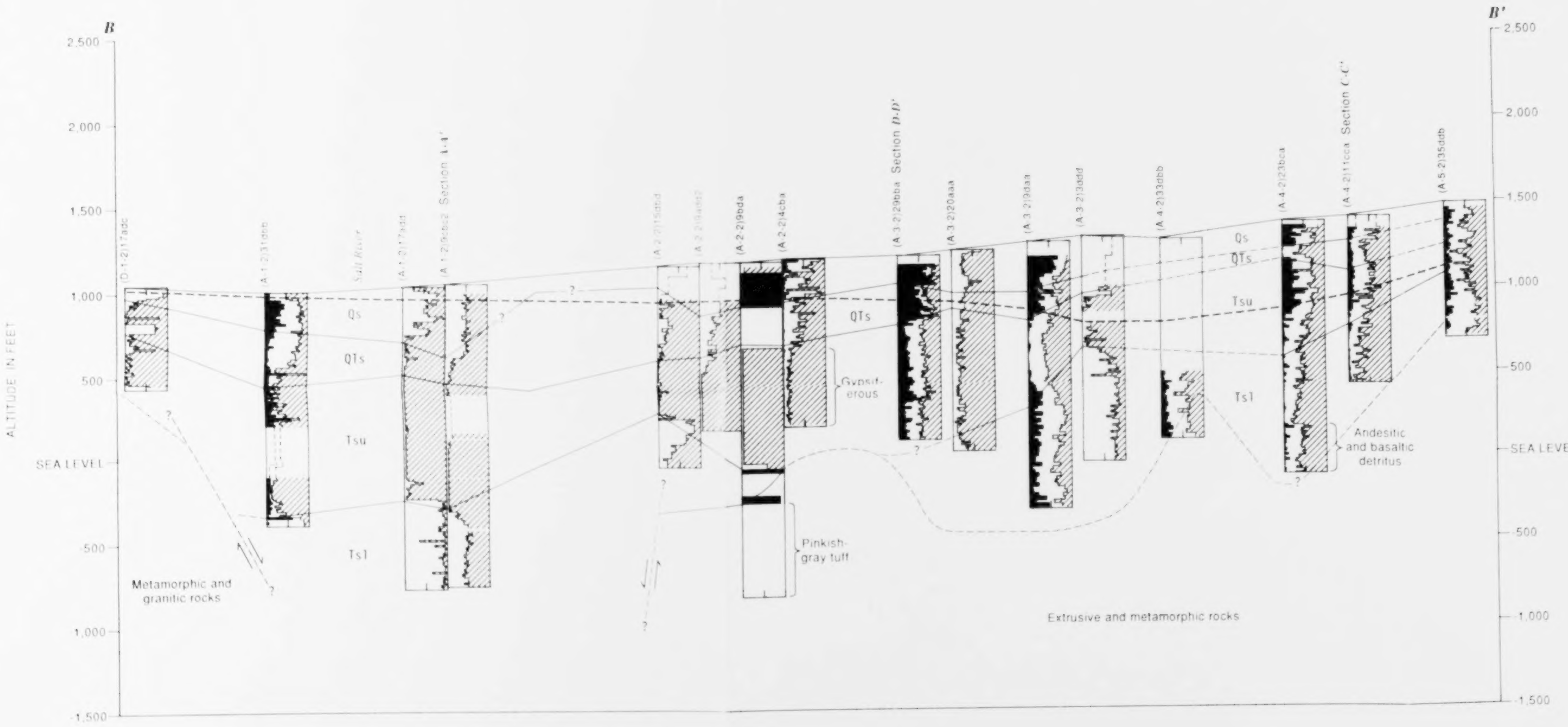
(B-2-2)10ccc WELL AND LOCATION—See figure 4 for well-numbering system in Arizona

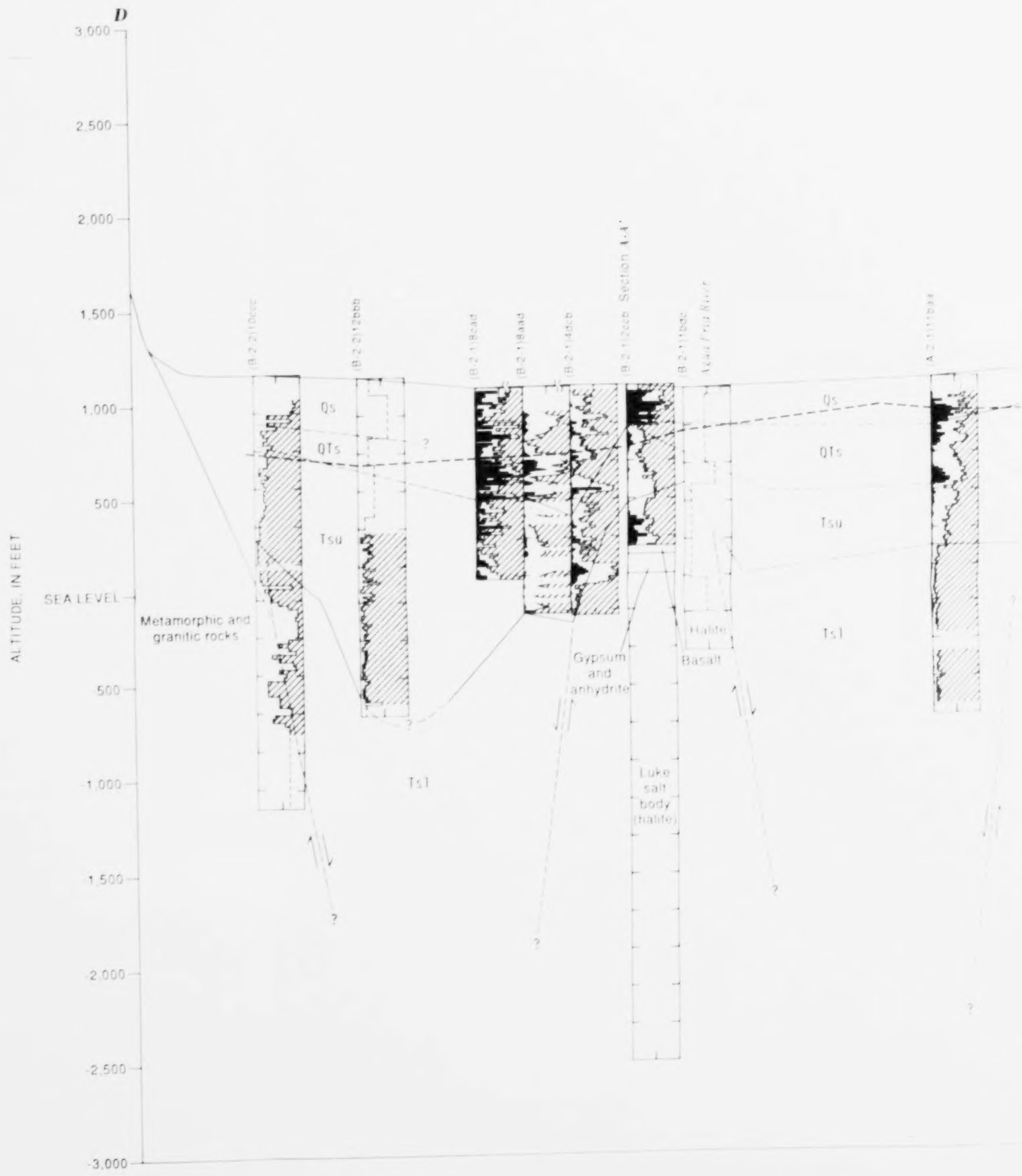
— — — — APPROXIMATE WATER LEVEL, NOVEMBER 1984 TO JANUARY 1985

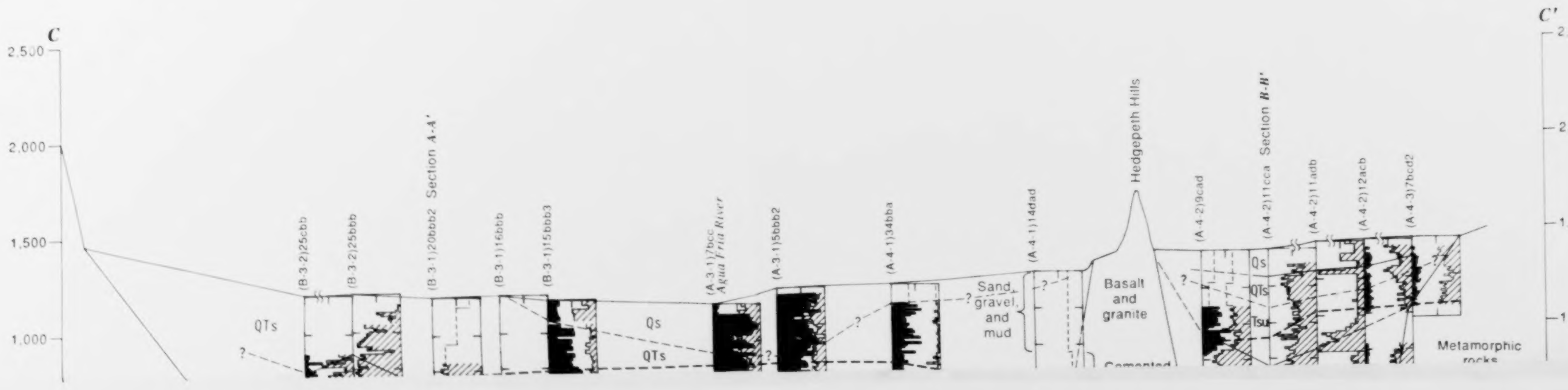
PERCENT SAND AND GRAVEL—(>0.062 millimeter in diameter) average for 10-foot or 20-foot section of unit. Graph on left shows percent sand and gravel undifferentiated (>0.062 millimeter in diameter); graph on right shows percent sand (0.062 to 2.0 millimeters in diameter) and percent gravel (>2.0 millimeters in diameter). Dashed where estimated from drillers' logs or lithologic logs

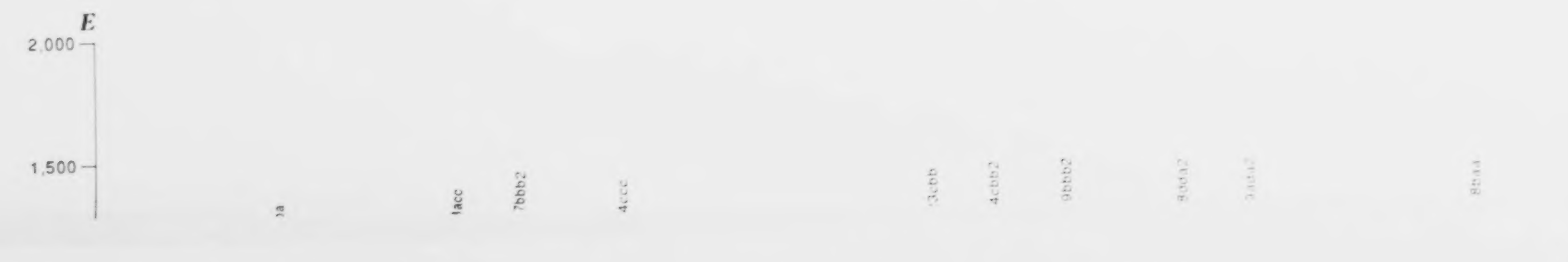


NATIONAL GEODETIC VERTICAL DATUM OF 1929
VERTICAL SCALE GREATLY EXAGGERATED









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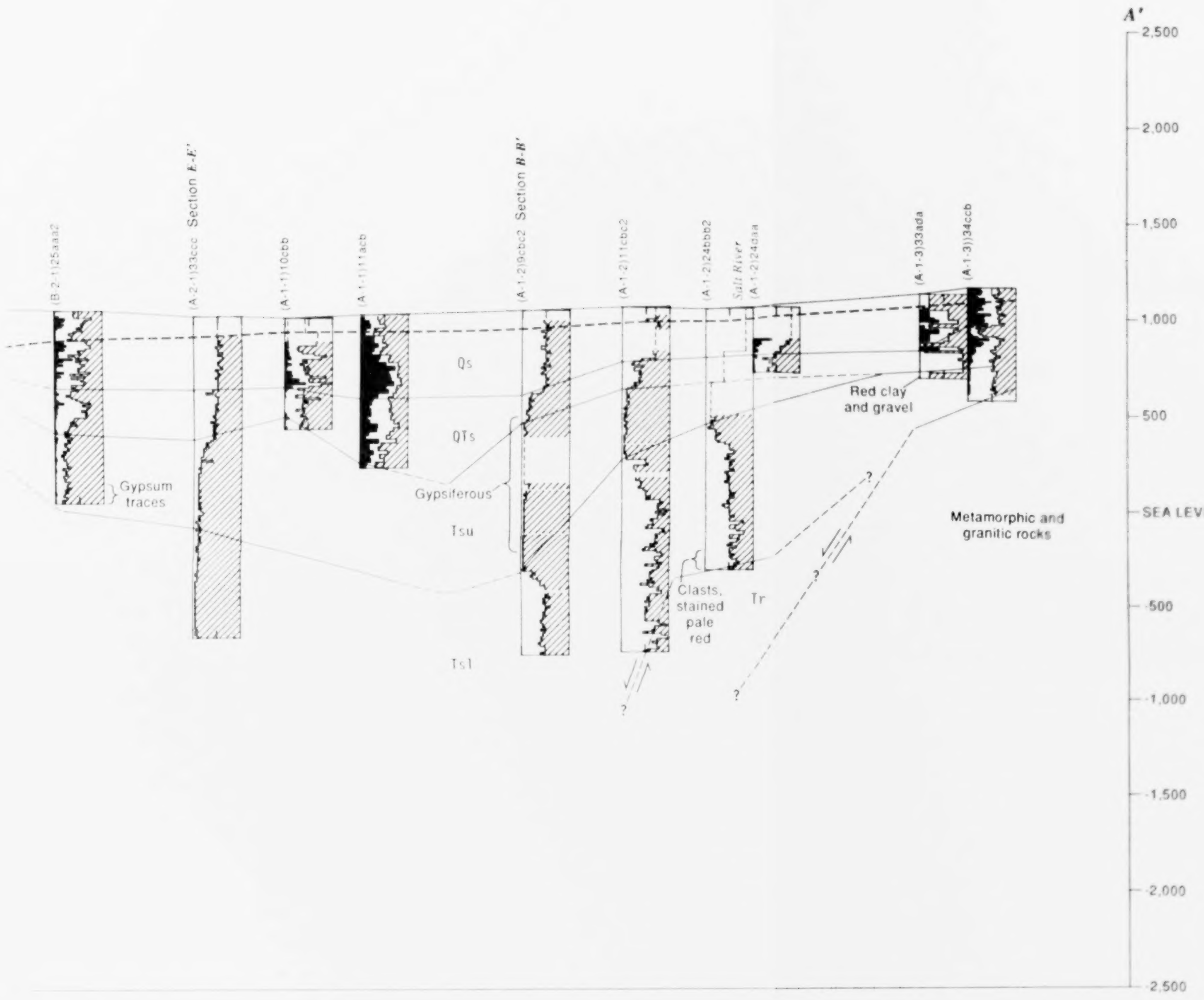
WATER-RESOURCES INVESTIGATIONS REPORT 88-4202
SHEET 2 OF 5



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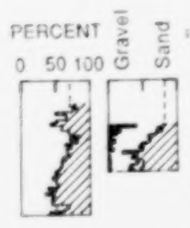
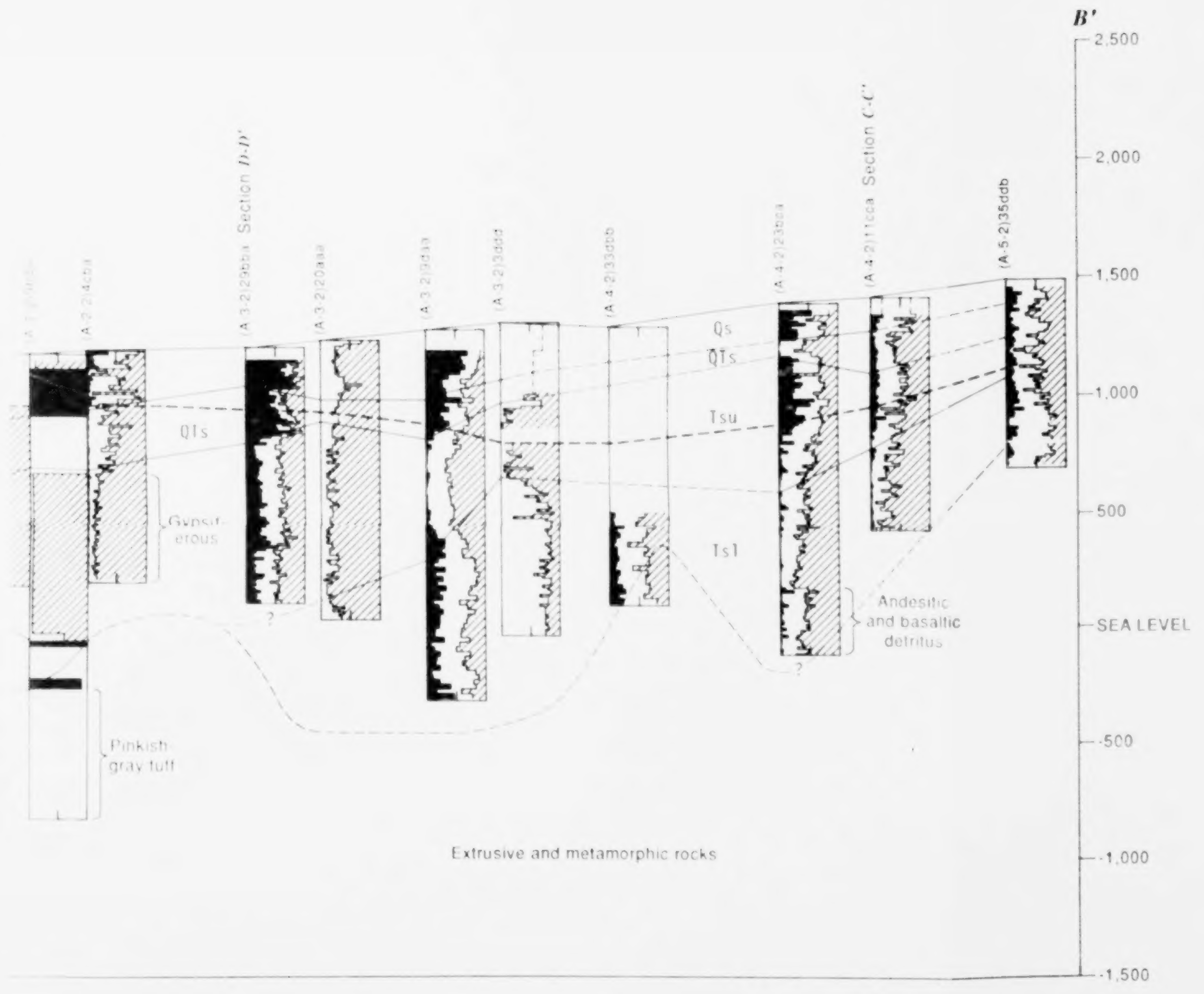
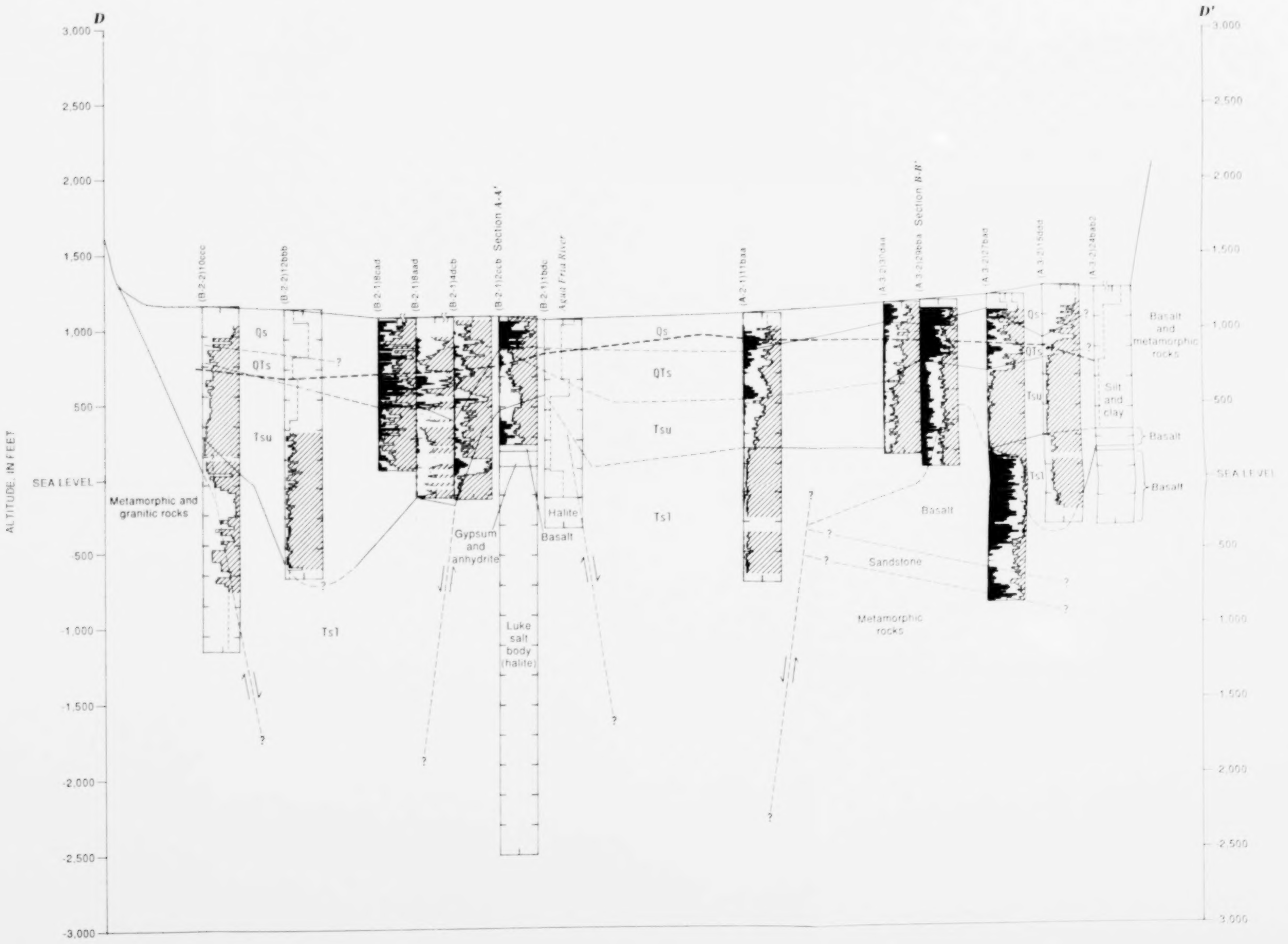
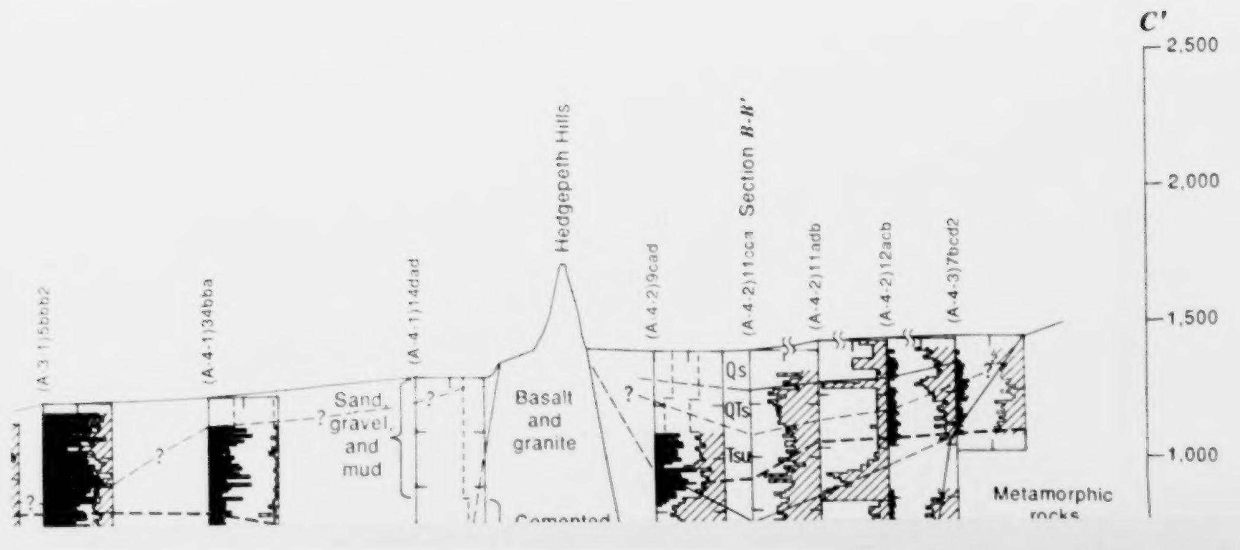


PERCENT SAND AND GRAVEL—(>0.062 millimeter in diameter) average for 10-foot or 20-foot section of unit. Graph on left shows percent sand and gravel undifferentiated (>0.062 millimeter in diameter); graph on right shows percent sand (0.062 to 2.0 millimeters in diameter) and percent gravel (>2.0 millimeters in diameter). Dashed where estimated from drillers' logs or lithologic logs

NATIONAL GEODETIC VERTICAL DATUM OF 1929
VERTICAL SCALE GREATLY EXAGGERATED







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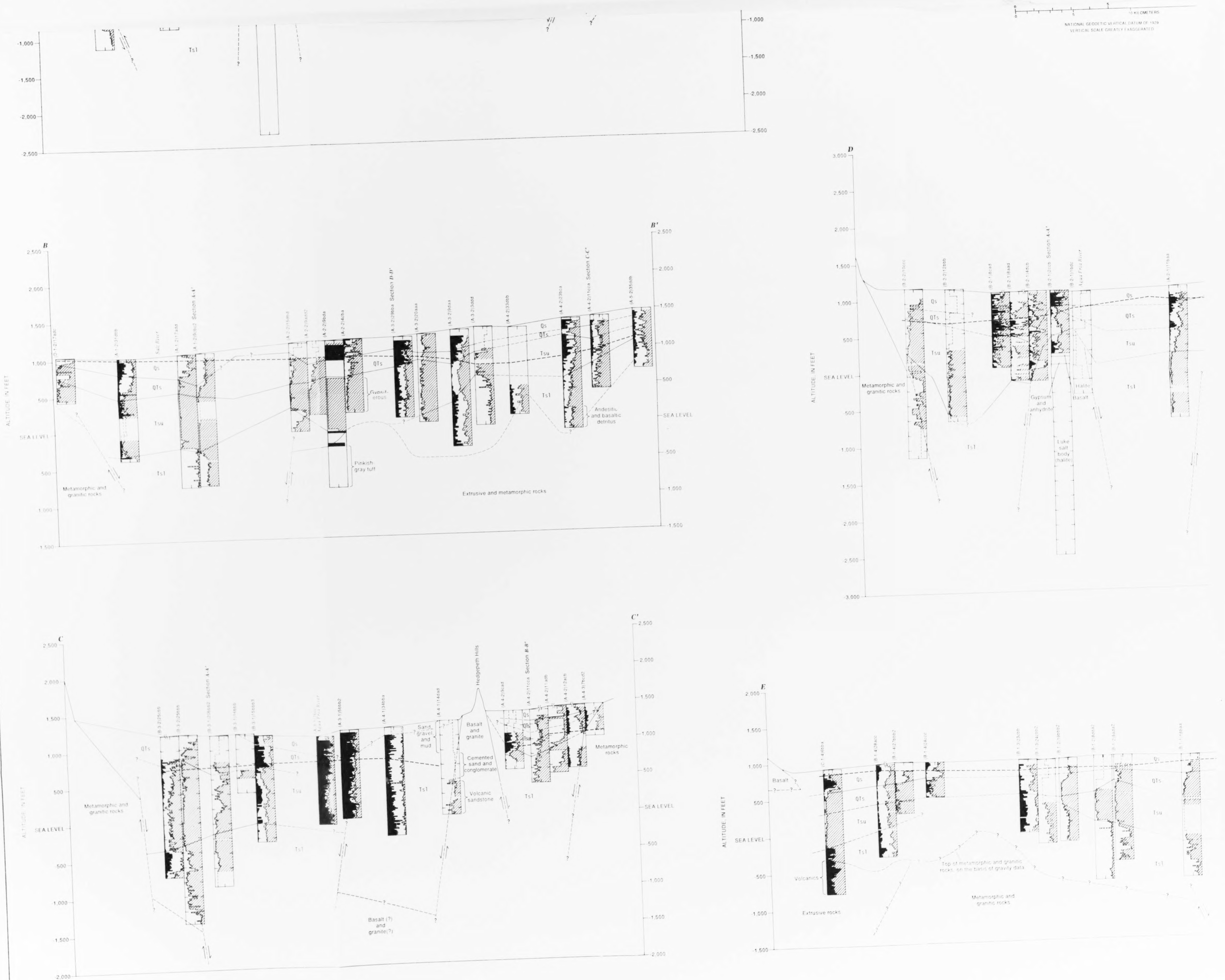

Figure 6.--Hydrogeologic sections.

HYDROGEOLOGY OF THE WESTERN PART OF THE SALT RIVER VALLEY AREA, MARICOPA COUNTY, ARIZONA

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1989

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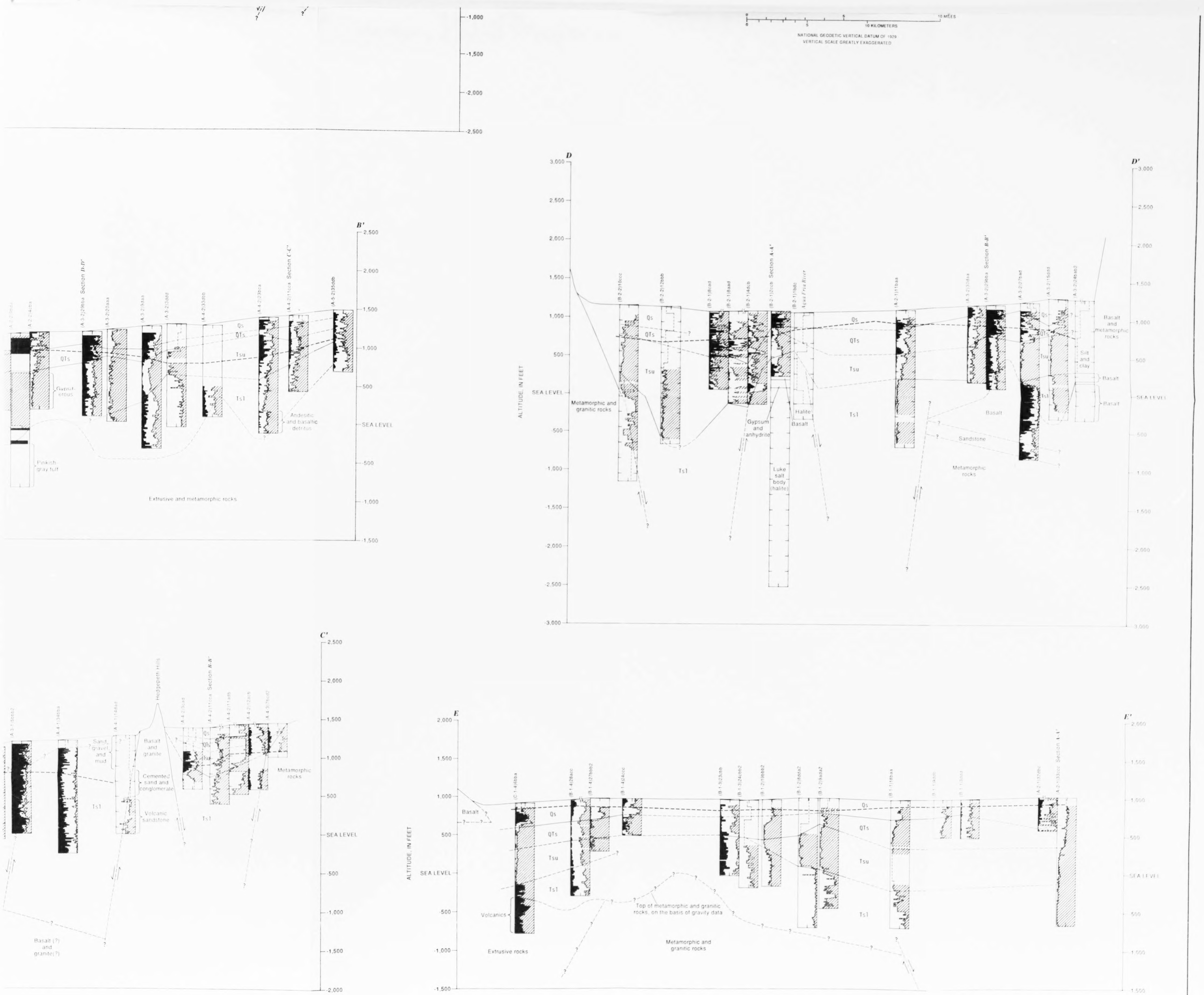

NATIONAL GEODETIC VERTICAL DATUM OF 1929
VERTICAL SCALE GREATLY EXAGGERATED
10 KILOMETERS
10 MILES
B'
C'
D
D'
E
E'
ALTITUDE, IN FEET
SEA LEVEL
Section A-A'
Section B-B'
Section C-C'
Section D-D'
Qs
QTs
Tsu
Ts1
Gypsiferous
Pinkish gray tuff
Andesitic and basaltic detritus
Extrusive and metamorphic rocks
Metamorphic and granitic rocks
Gypsum and anhydrite
Halite
Basalt
Luke salt body (halite)
Sandstone
Metamorphic rocks
Basalt and metamorphic rocks
Silt and clay
Hedgpeth Hills
Sand, gravel, and mud
Basalt and granite
Cemented sand and conglomerate
Volcanic sandstone
Basalt (?) and granite(?)
Volcanics
Extrusive rocks
Top of metamorphic and granitic rocks, on the basis of gravity data
Metamorphic and granitic rocks

Figure 6.--Hydrogeologic sections.

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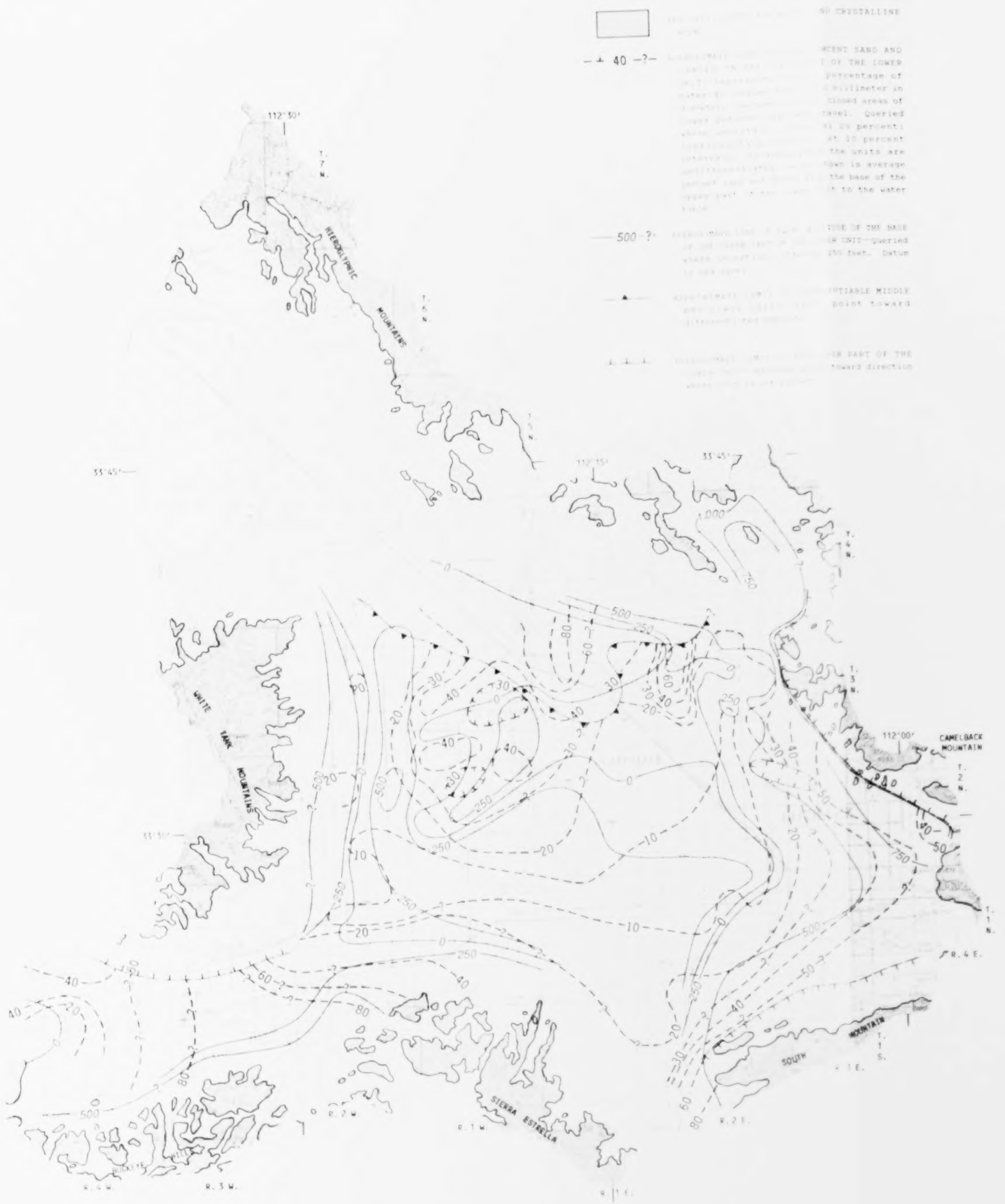


EXPLANATION

▭ [illegible] —Includes [illegible]

▨ [illegible] CRYSTALLINE [illegible]

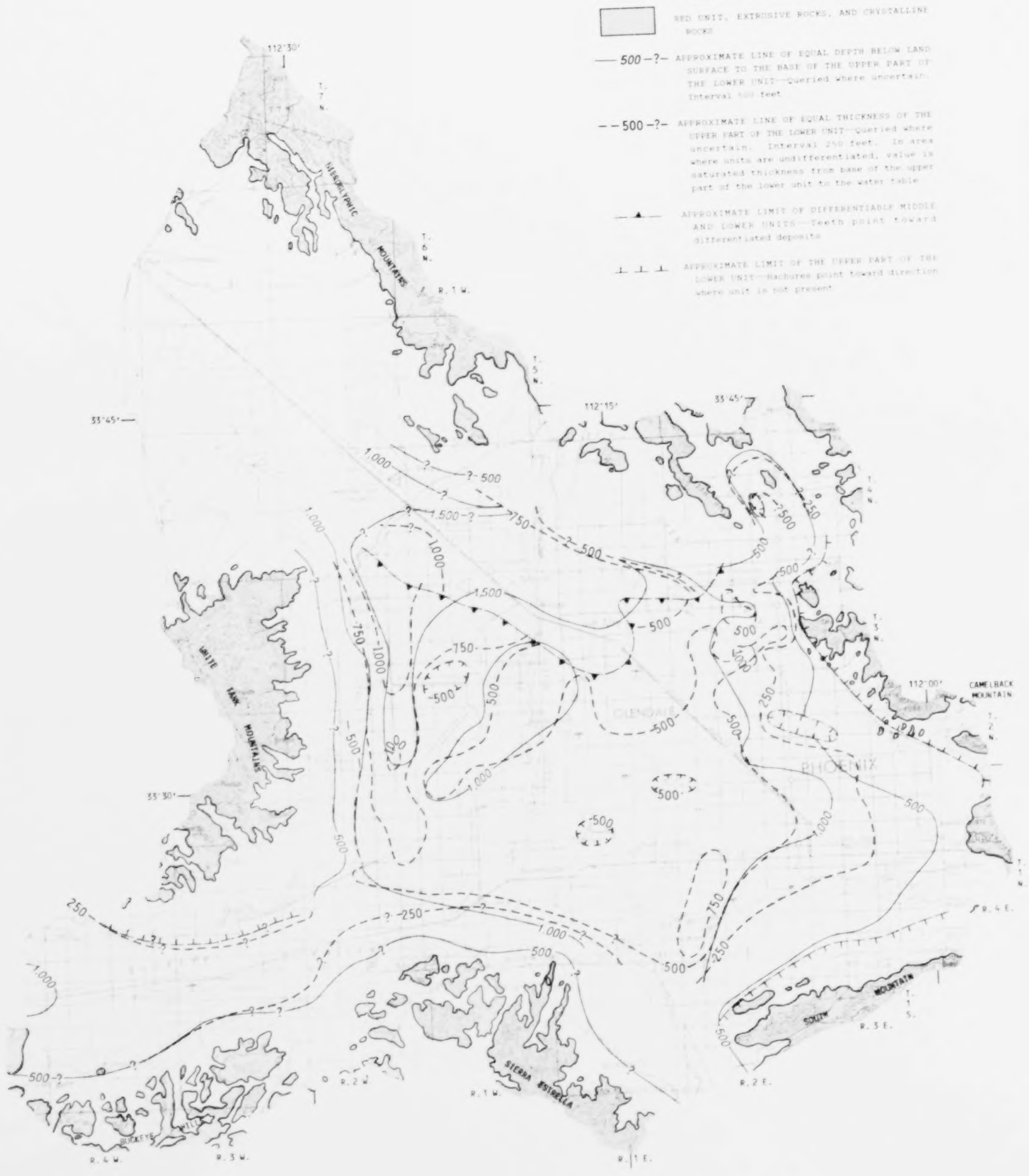
— ▲ 40 —?— [illegible] PERCENT SAND AND [illegible] OF THE LOWER [illegible] percentage of [illegible] millimeter in [illegible] Closed areas of [illegible] gravel. Queried [illegible] 20 percent; [illegible] at 10 percent [illegible] the units are [illegible] shown is average [illegible] the base of the [illegible] to the water table

——500—?— [illegible] OF THE BASE [illegible] UNIT—Queried [illegible] 250 feet. Datum [illegible]

—▲— [illegible] DIFFERENTIABLE MIDDLE [illegible] point toward [illegible]

⊥⊥⊥ [illegible] PART OF THE [illegible] toward direction [illegible]

Figure 7.--Altitude of the base and percent sand and gravel in the upper part of the lower unit.



EXPLANATION

▭ UNCONSOLIDATED SEDIMENTARY DEPOSITS—Includes upper, middle, and lower units

▨ RED UNIT, EXTRUSIVE ROCKS, AND CRYSTALLINE ROCKS

——500—?— APPROXIMATE LINE OF EQUAL DEPTH BELOW LAND SURFACE TO THE BASE OF THE UPPER PART OF THE LOWER UNIT—Queried where uncertain. Interval 500 feet

– –500—?— APPROXIMATE LINE OF EQUAL THICKNESS OF THE UPPER PART OF THE LOWER UNIT—Queried where uncertain. Interval 250 feet. In area where units are undifferentiated, value is saturated thickness from base of the upper part of the lower unit to the water table

—▲— APPROXIMATE LIMIT OF DIFFERENTIABLE MIDDLE AND LOWER UNITS—Teeth point toward differentiated deposits

⊥ ⊥ ⊥ APPROXIMATE LIMIT OF THE UPPER PART OF THE LOWER UNIT—Hachures point toward direction where unit is not present

Figure 8.--Depth to the base and thickness of the upper part of the lower unit.

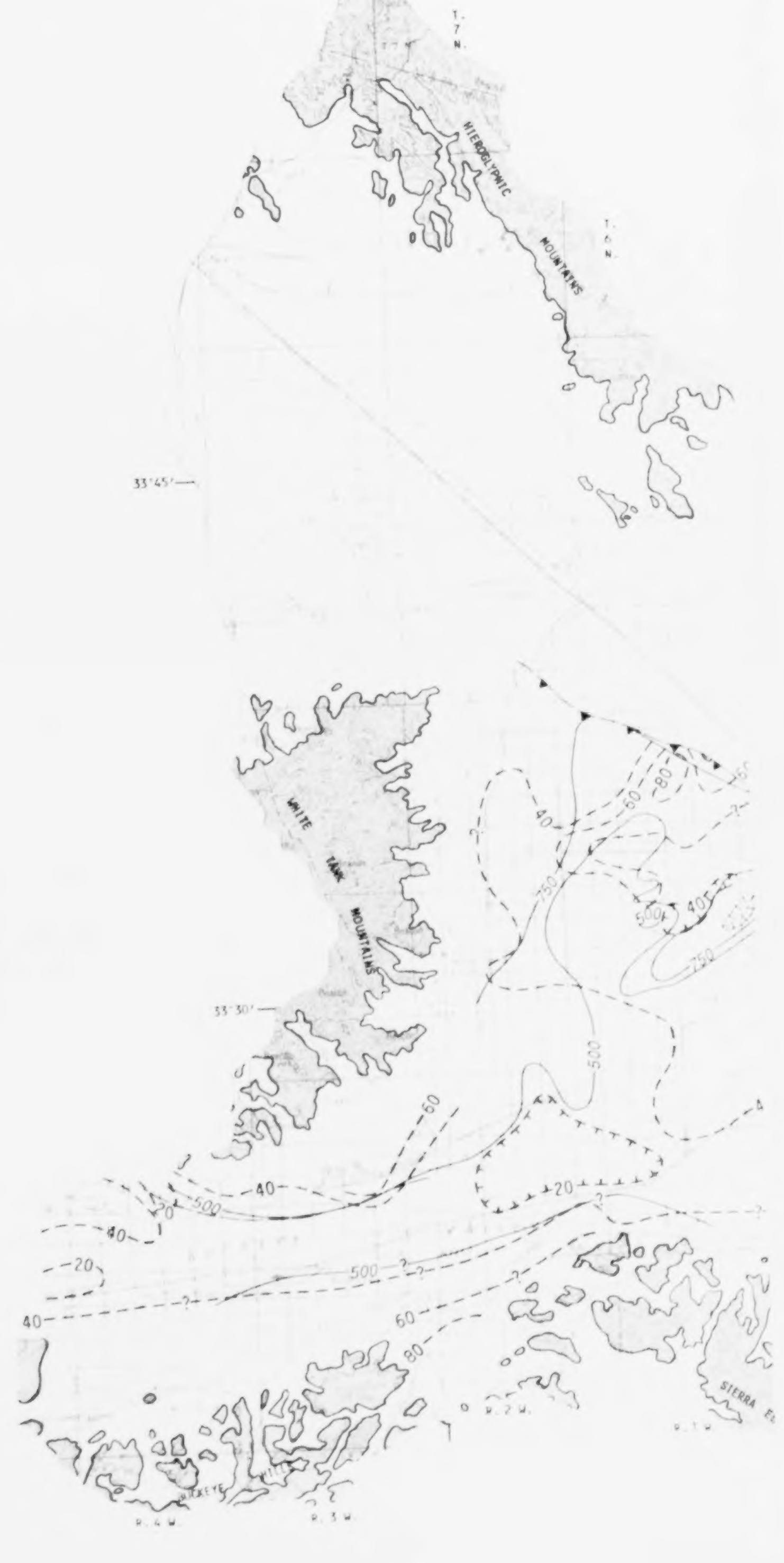
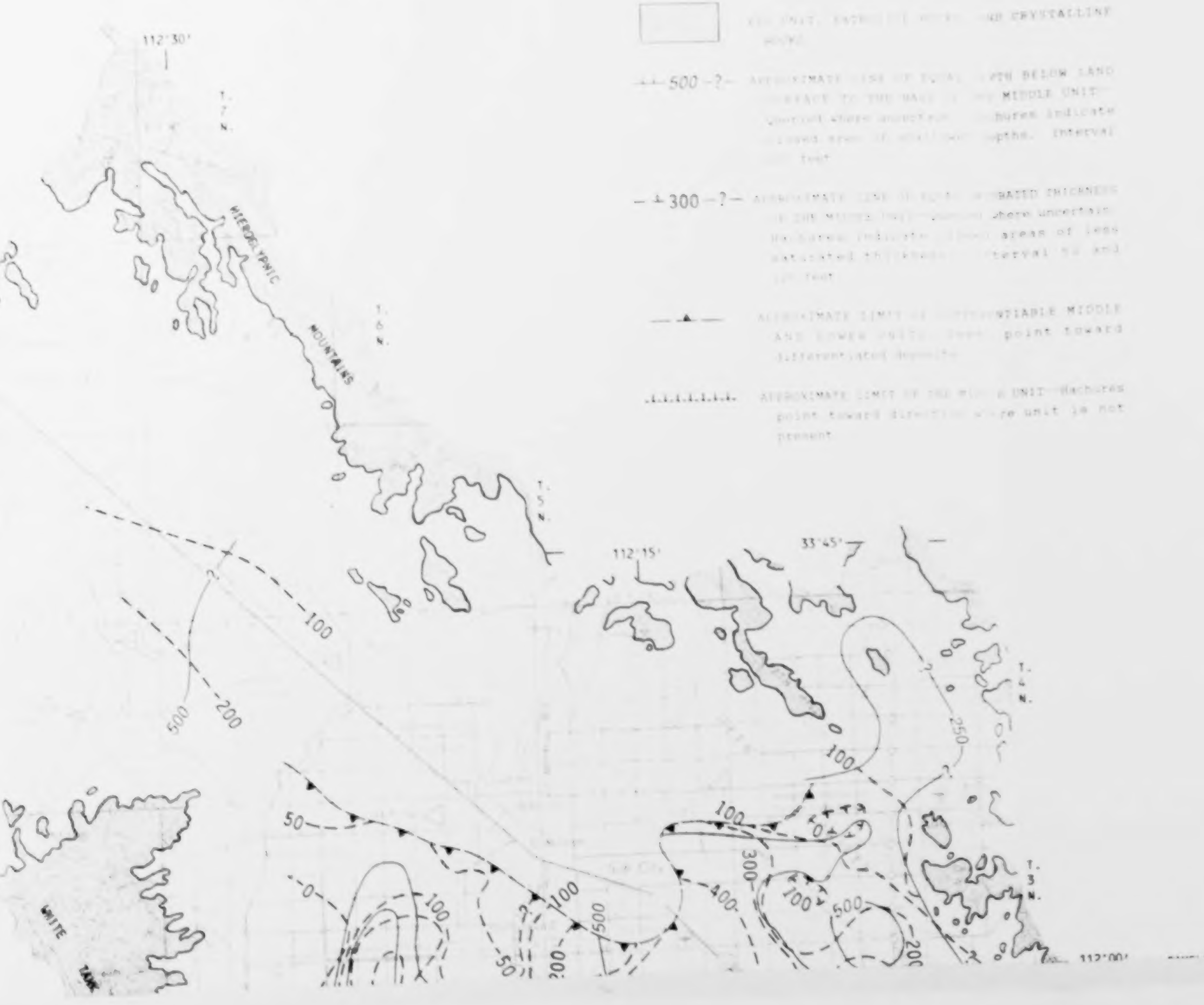


Figure 9.--Altitude of the base and perce



EXPLANATION

▭ UNCONSOLIDATED SEDIMENTARY DEPOSITS—Includes upper, middle, and lower units

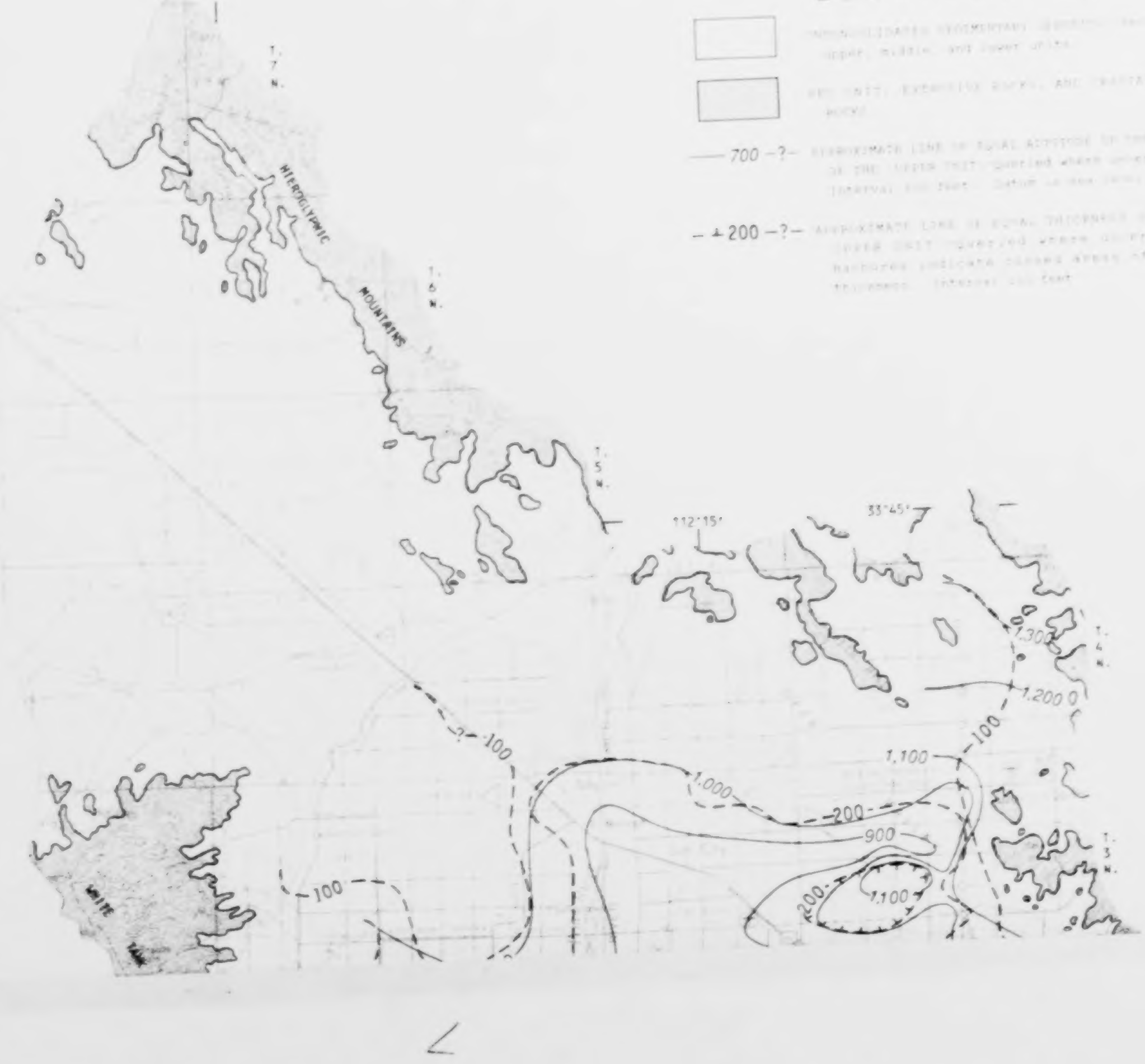
▨ RED UNIT, EXTRUSIVE ROCKS, AND CRYSTALLINE ROCKS

– –500—?— APPROXIMATE LINE OF EQUAL DEPTH BELOW LAND SURFACE TO THE BASE OF THE MIDDLE UNIT—Queried where uncertain. Hachures indicate closed areas of shallower depths. Interval 100 feet

– ▲300—?— APPROXIMATE LINE OF EQUAL SATURATED THICKNESS OF THE MIDDLE UNIT—Queried where uncertain. Hachures indicate closed areas of less saturated thickness. Interval 50 and 100 feet

—▲— APPROXIMATE LIMIT OF DIFFERENTIABLE MIDDLE AND LOWER UNITS—Teeth point toward differentiated deposits

⊥⊥⊥⊥⊥⊥⊥ APPROXIMATE LIMIT OF THE MIDDLE UNIT—Hachures point toward direction where unit is not present



EXPLANATION

▭ UNCONSOLIDATED SEDIMENTARY DEPOSITS—Includes upper, middle, and lower units

▨ RED UNIT, EXTRUSIVE ROCKS, AND CRYSTALLINE ROCKS

——700—?— APPROXIMATE LINE OF EQUAL ALTITUDE OF THE BASE OF THE UPPER UNIT—Queried where uncertain. Interval 100 feet. Datum is sea level

– ▲200—?— APPROXIMATE LINE OF EQUAL THICKNESS OF THE UPPER UNIT—Queried where uncertain. Hachures indicate closed areas of less thickness. Interval 100 feet

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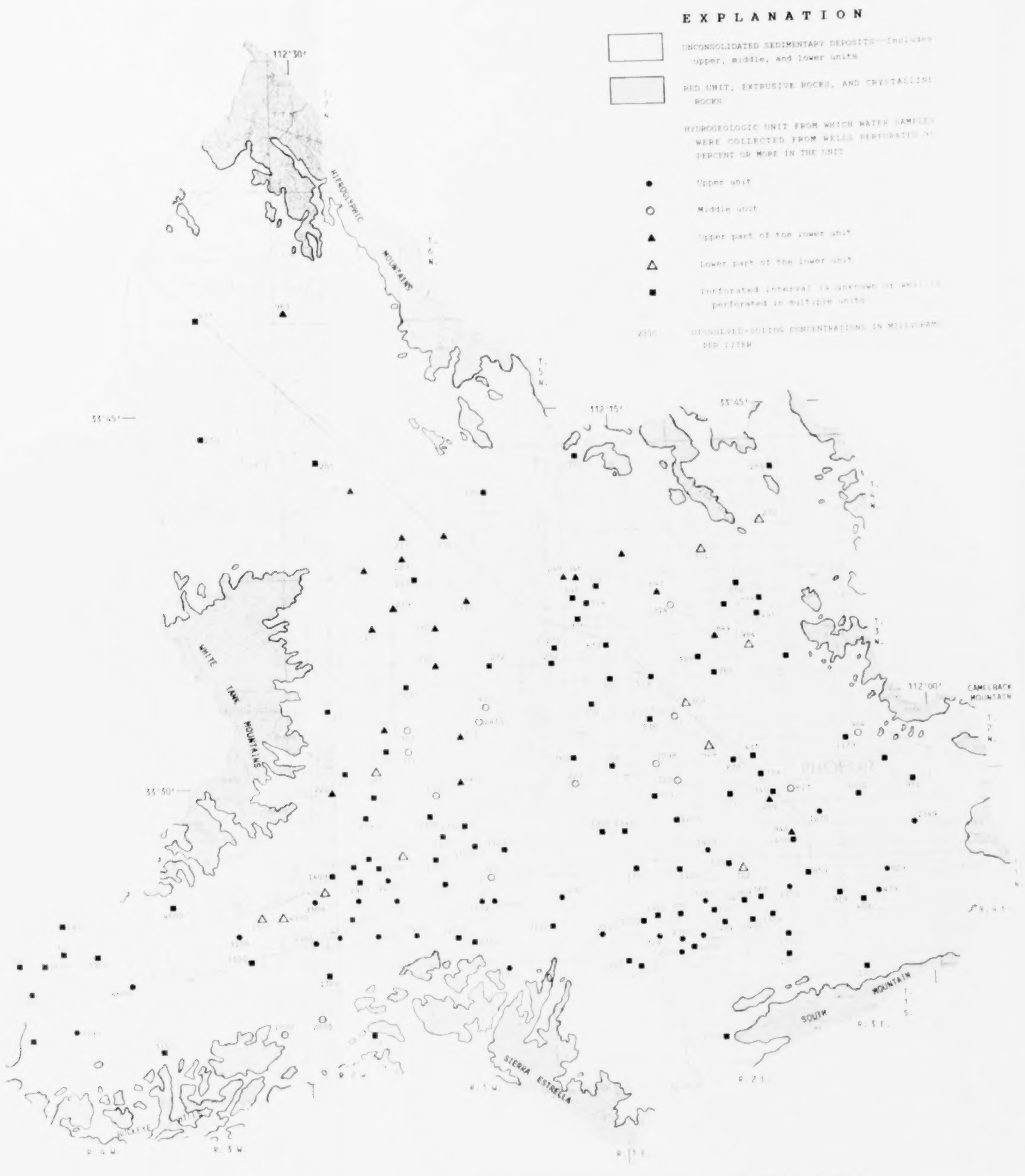

EXPLANATION
UNCONSOLIDATED SEDIMENTARY DEPOSITS--Includes upper, middle, and lower units
RED UNIT, EXTRUSIVE ROCKS, AND CRYSTALLINE ROCKS
HYDROGEOLOGIC UNIT FROM WHICH WATER SAMPLES WERE COLLECTED FROM WELLS PERFORATED 70 PERCENT OR MORE IN THE UNIT
● Upper unit
○ Middle unit
▲ Upper part of the lower unit
△ Lower part of the lower unit
■ Perforated interval is unknown or well is perforated in multiple units
2150 DISSOLVED-SOLIDS CONCENTRATIONS IN MILLIGRAMS PER LITER
112°30'
112°15'
33°45'
T. 5 N.
T. 4 N.

Figure 13.--Dissolved-solids concentrations in water from selected wells, 1980-85.

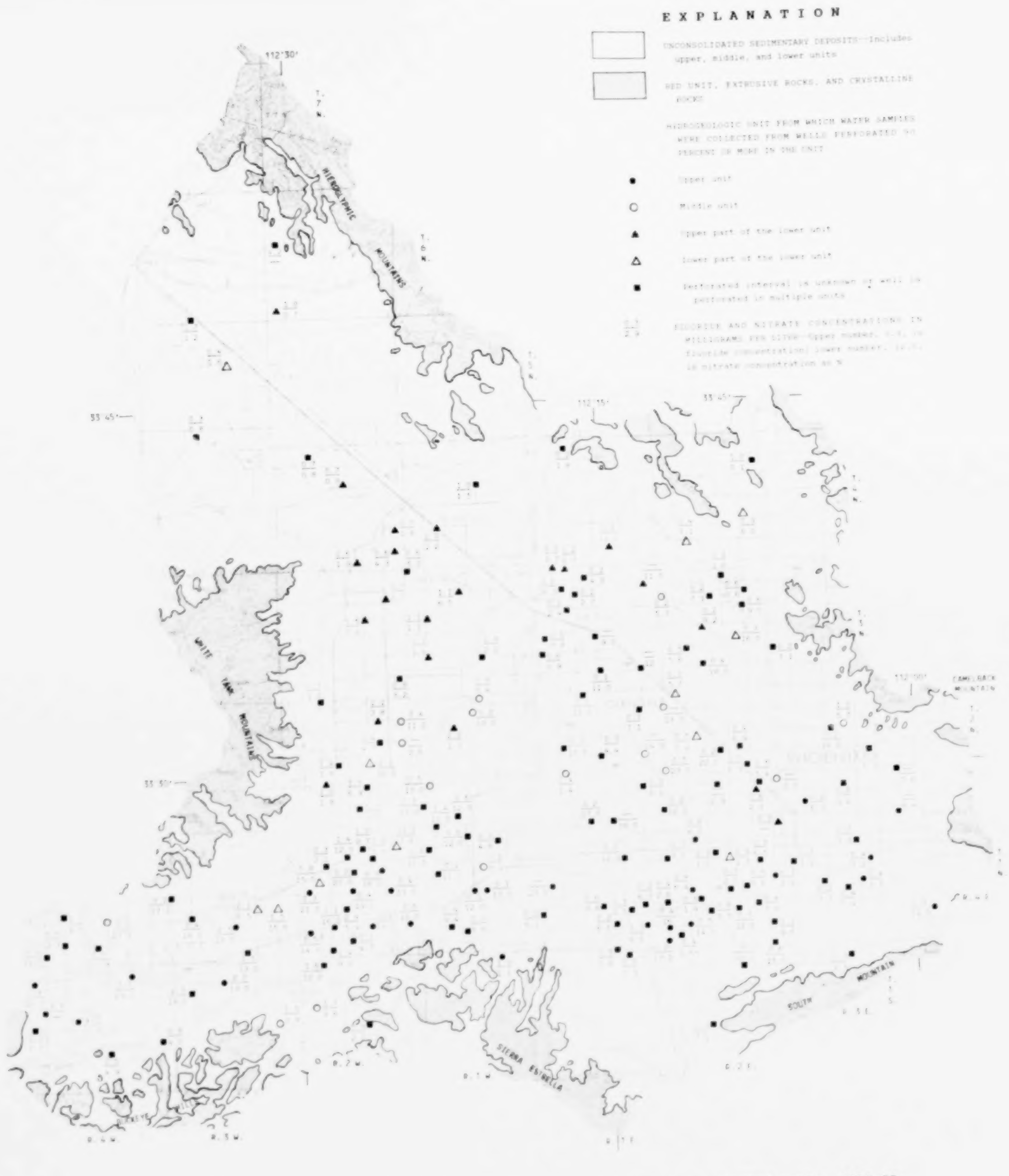

EXPLANATION
UNCONSOLIDATED SEDIMENTARY DEPOSITS--Includes upper, middle, and lower units
RED UNIT, EXTRUSIVE ROCKS, AND CRYSTALLINE ROCKS
HYDROGEOLOGIC UNIT FROM WHICH WATER SAMPLES WERE COLLECTED FROM WELLS PERFORATED 70 PERCENT OR MORE IN THE UNIT
● Upper unit
○ Middle unit
▲ Upper part of the lower unit
△ Lower part of the lower unit
■ Perforated interval is unknown or well is perforated in multiple units
FLUORIDE AND NITRATE CONCENTRATIONS IN MILLIGRAMS PER LITER--Upper number is fluoride concentration; lower number is nitrate concentration as N
112°30'
112°15'
33°45'
T. 5 N.
T. 4 N.

Figure 14.--Fluoride and nitrate concentrations in water from selected wells, 1980-85.

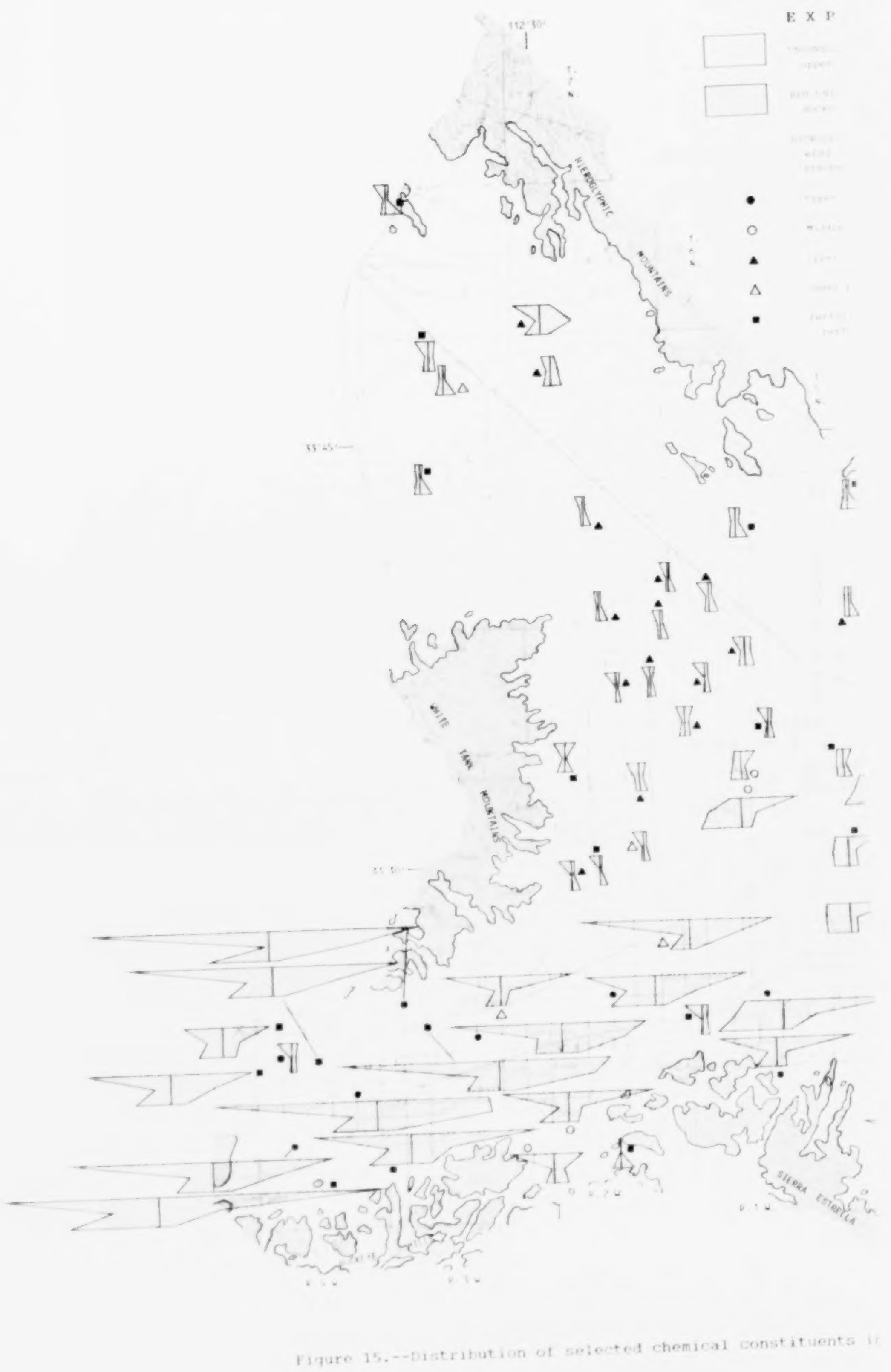


Figure 15.--Distribution of selected chemical constituents i

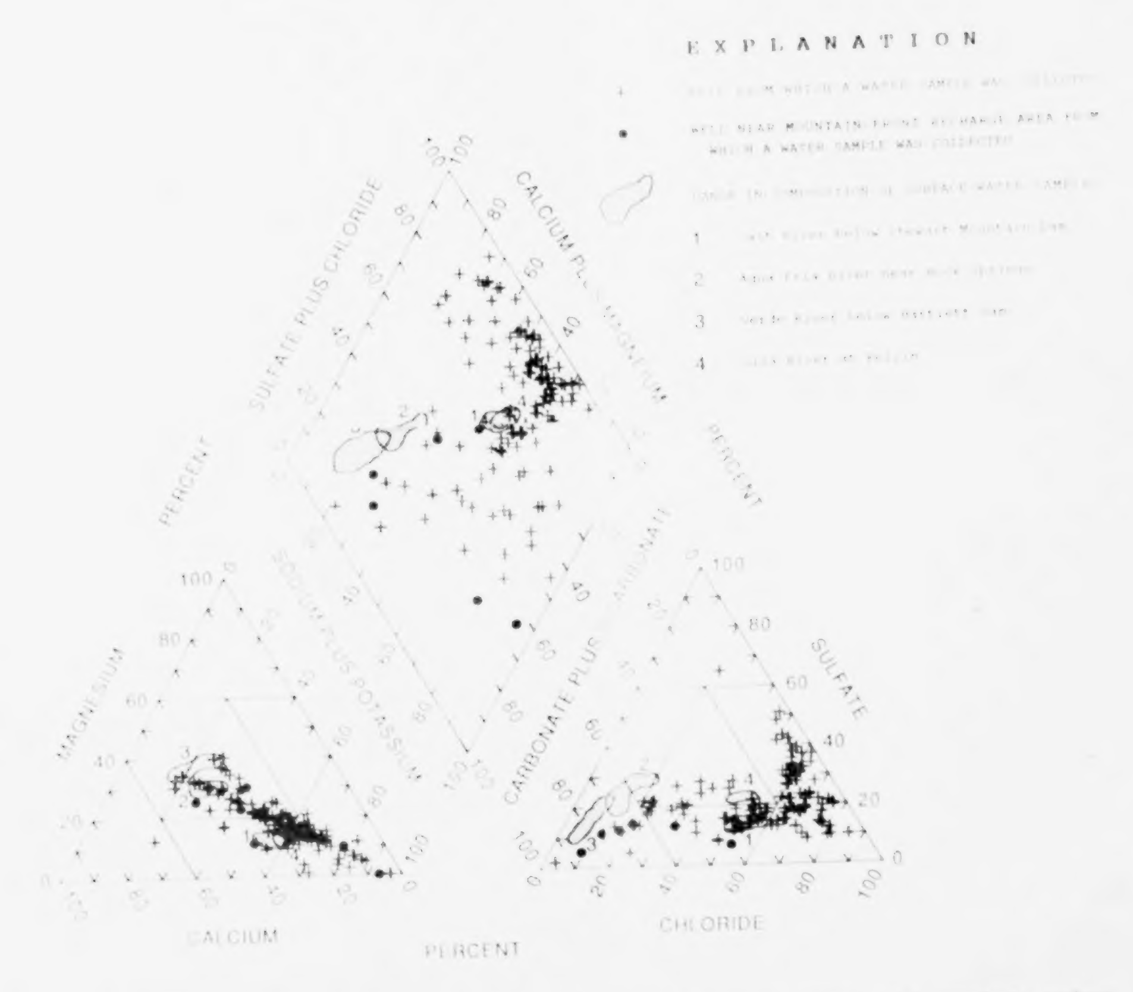


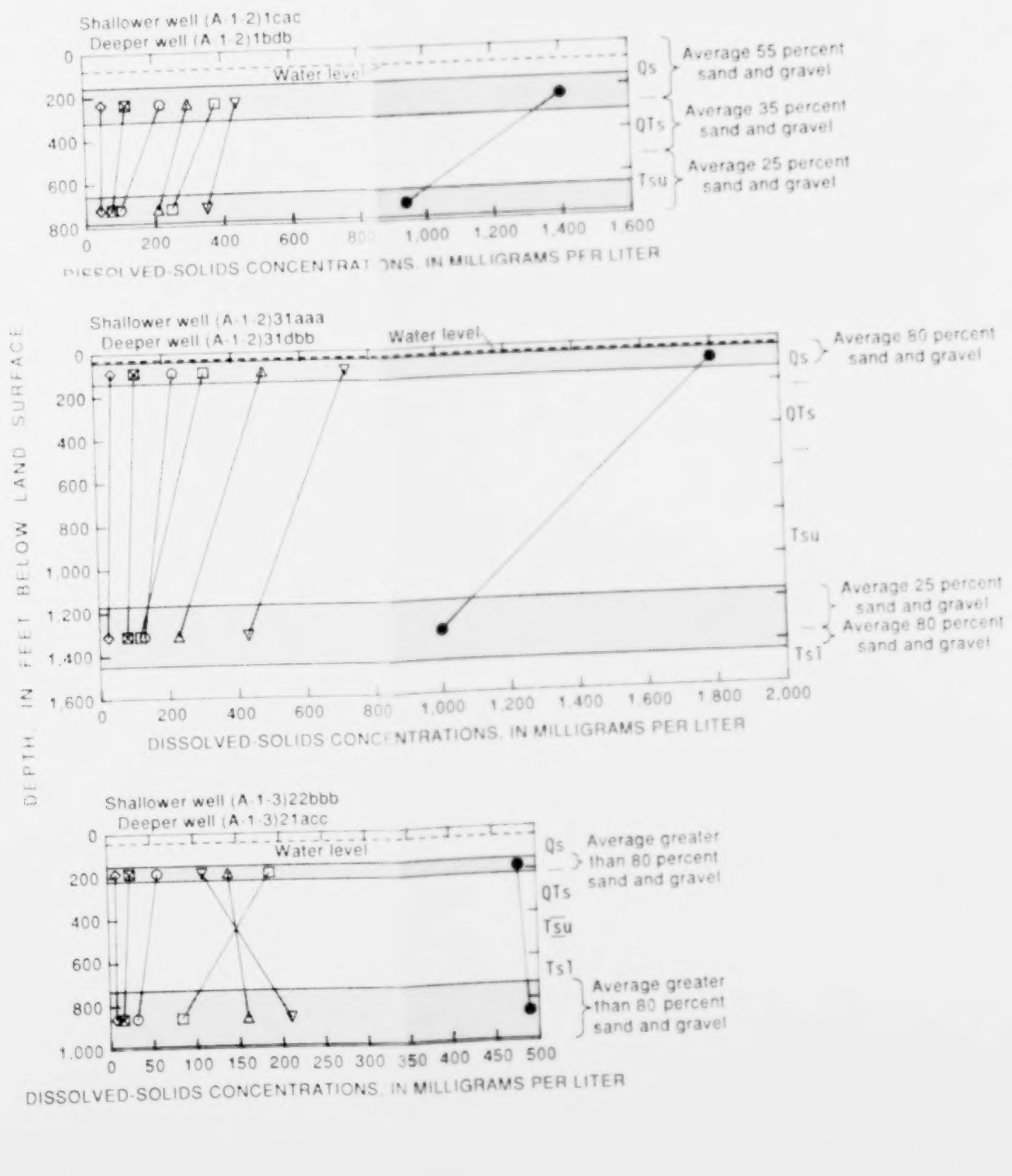
Figure 16.--Percentages of chemical constituents in ground water and surface water.

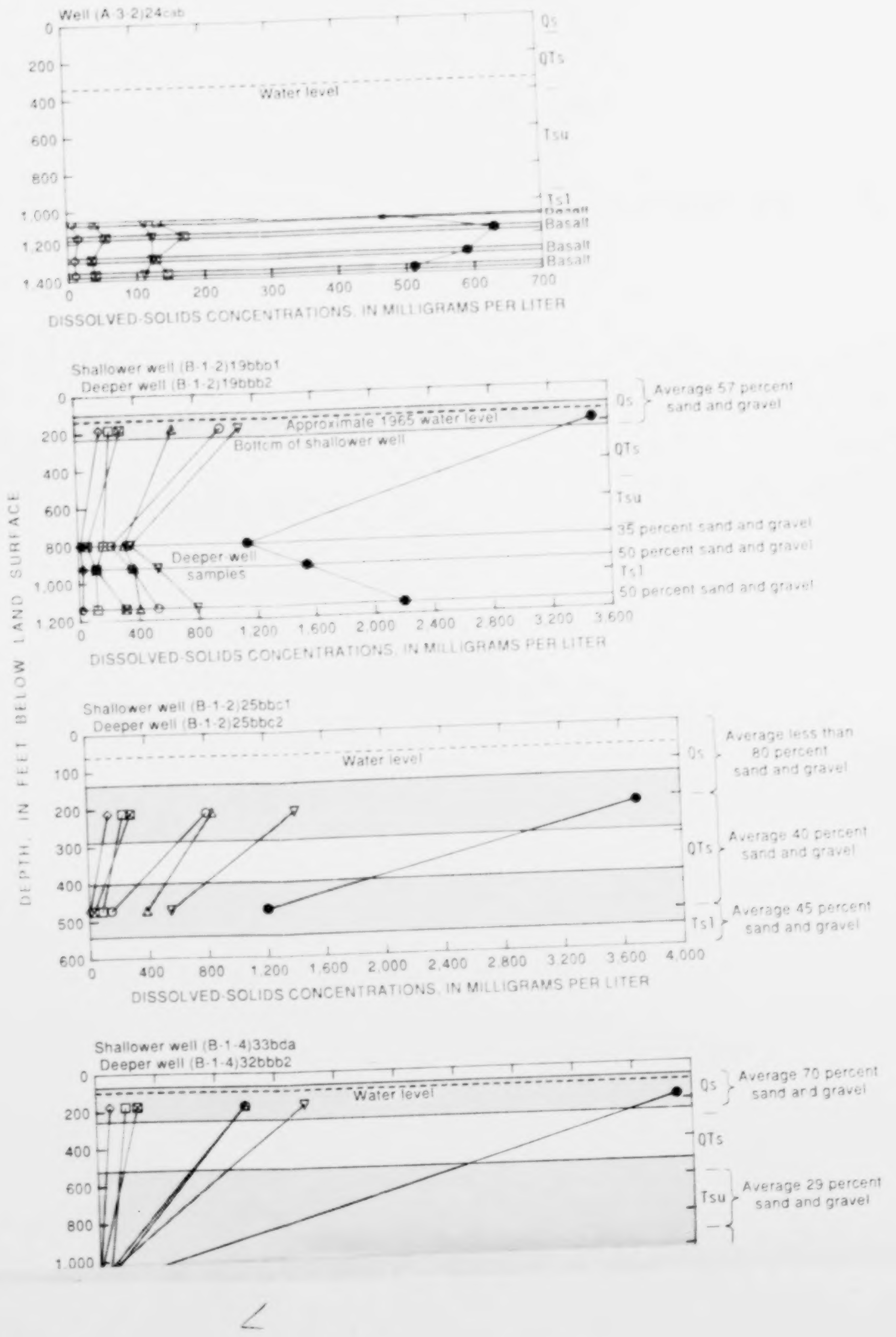
WATER QUALITY

[illegible] in the study area is the result of the natural [illegible] that occur in the subsurface and, to a lesser extent, the effects of human activities. Water quality in the western part of the Salt River Valley [illegible]. Dissolved-solids concentrations in ground water may exceed [illegible] mg/L adjacent to the Gila River (fig. 13) and exceed [illegible] mg/L at depth near the Luke salt body. Water in the other parts of the valley generally is suitable for domestic supply but locally may exceed drinking-water standards for fluoride or nitrate (fig. 14; table 2). Principal ions dissolved in the ground water are sodium, calcium, chloride, and bicarbonate. Waters are commonly classified on the basis of percentage concentrations of the major cations and anions in milliequivalents per liter. Classifying water as a sodium chloride type, for example, indicates that more than 50 percent of the dissolved cations are sodium and more than 50 percent of the dissolved anions are chloride. Water in which no ion is dominant is referred to as mixed.

Chemical Evolution of the Ground Water

Chemical evolution of ground water in alluvial basins is the result of a complex series of geochemical reactions, which





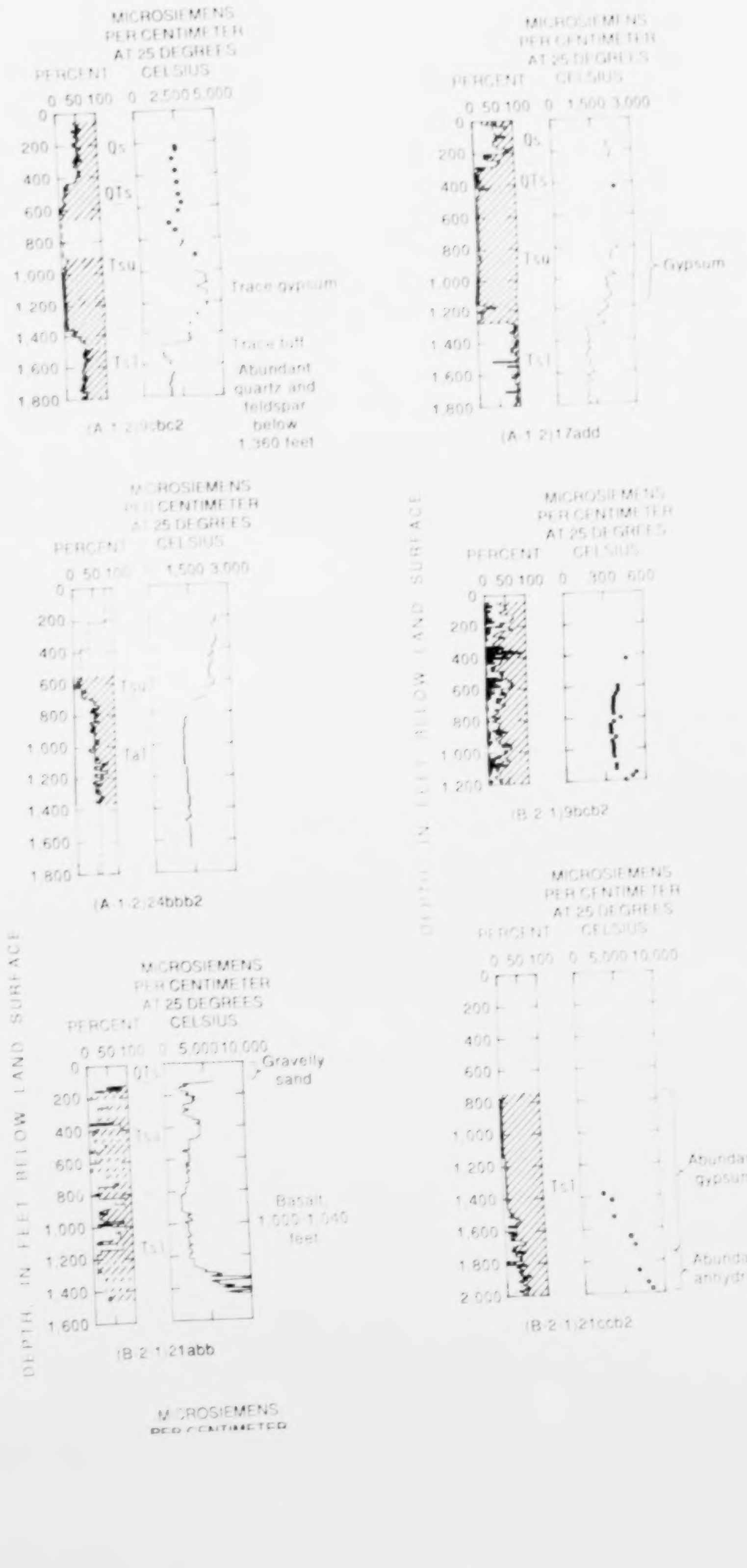


Table 2.--*Chemical analyses of water from selected wells*

[Ft, feet; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25° Celsius; <, less than; ----, indicates no data]

LOCAL IDENTI-	WELL DEPTH	DATE	TEMPER-ATURE WATER	PH (STAND-ARD	ALKA-LINITY LAB (mg/L as	CALCIUM DIS-SOLVED (mg/L	MAGNE-SIUM, DIS-SOLVED (mg/L	POTAS-SIUM, DIS-SOLVED (mg/L	SODIUM, DIS-SOLVED (mg/L	CHLO-RIDE, DIS-SOLVED (mg/L	SULFATE DIS-SOLVED (mg/L	FLUO-RIDE, DIS-SOLVED (mg/L	NITRO-GEN, NO2+NO3 DIS-SOLVED (mg/L	SILICA, DIS-SOLVED (mg/L as	CHRO-MIUM, HEXA-VALENT, DISSOLVED (µg/L	ARSENIC DIS-SOLVED (µg/L	MANGA-NESE, DIS-SOLVED (µg/L	SELE-NIUM, DIS-SOLVED (µg/L	SPE-CIFIC CON-DUCT-ANCE	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED

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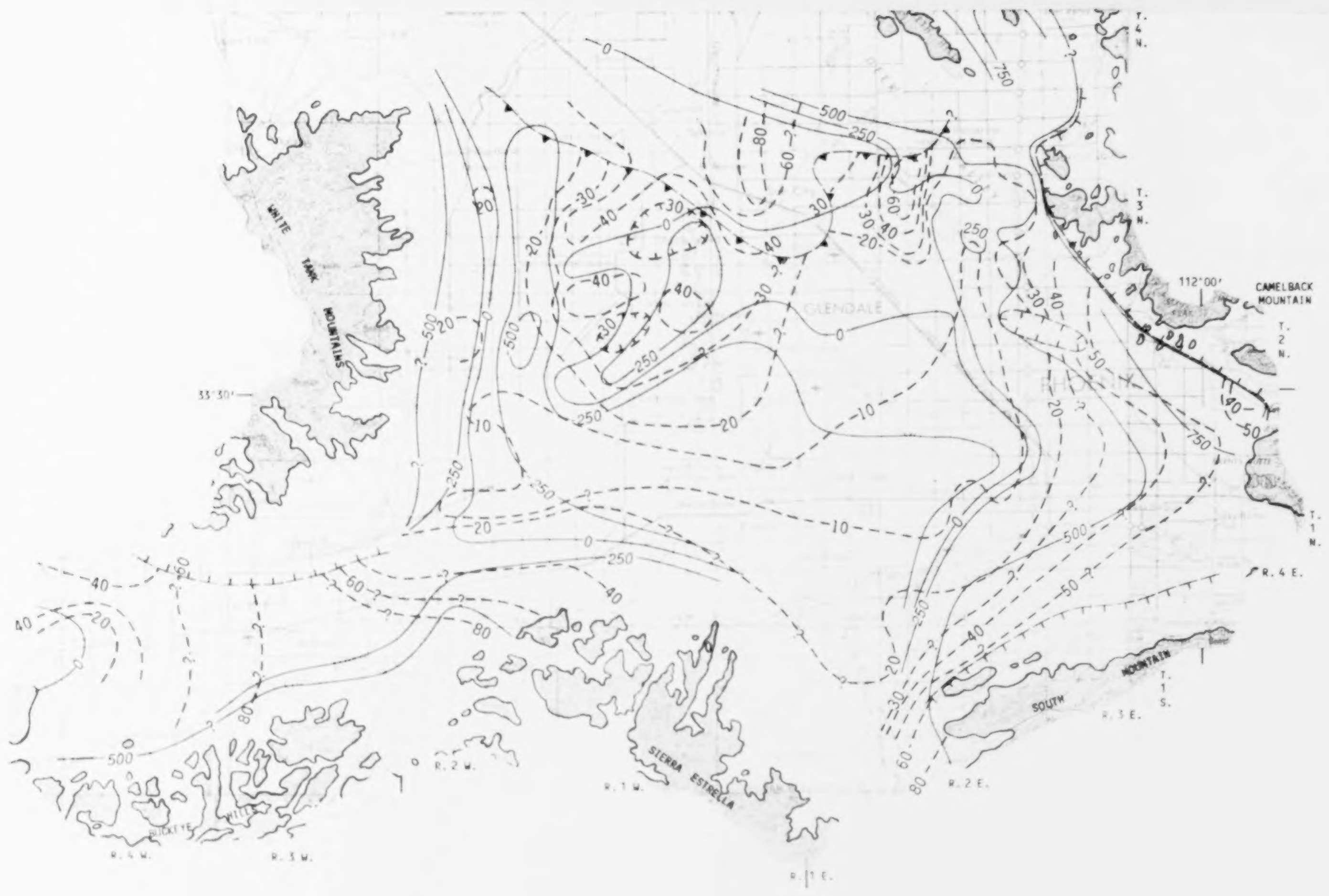

Figure 7.--Altitude of the base and percent sand and gravel in the upper part of the lower unit.

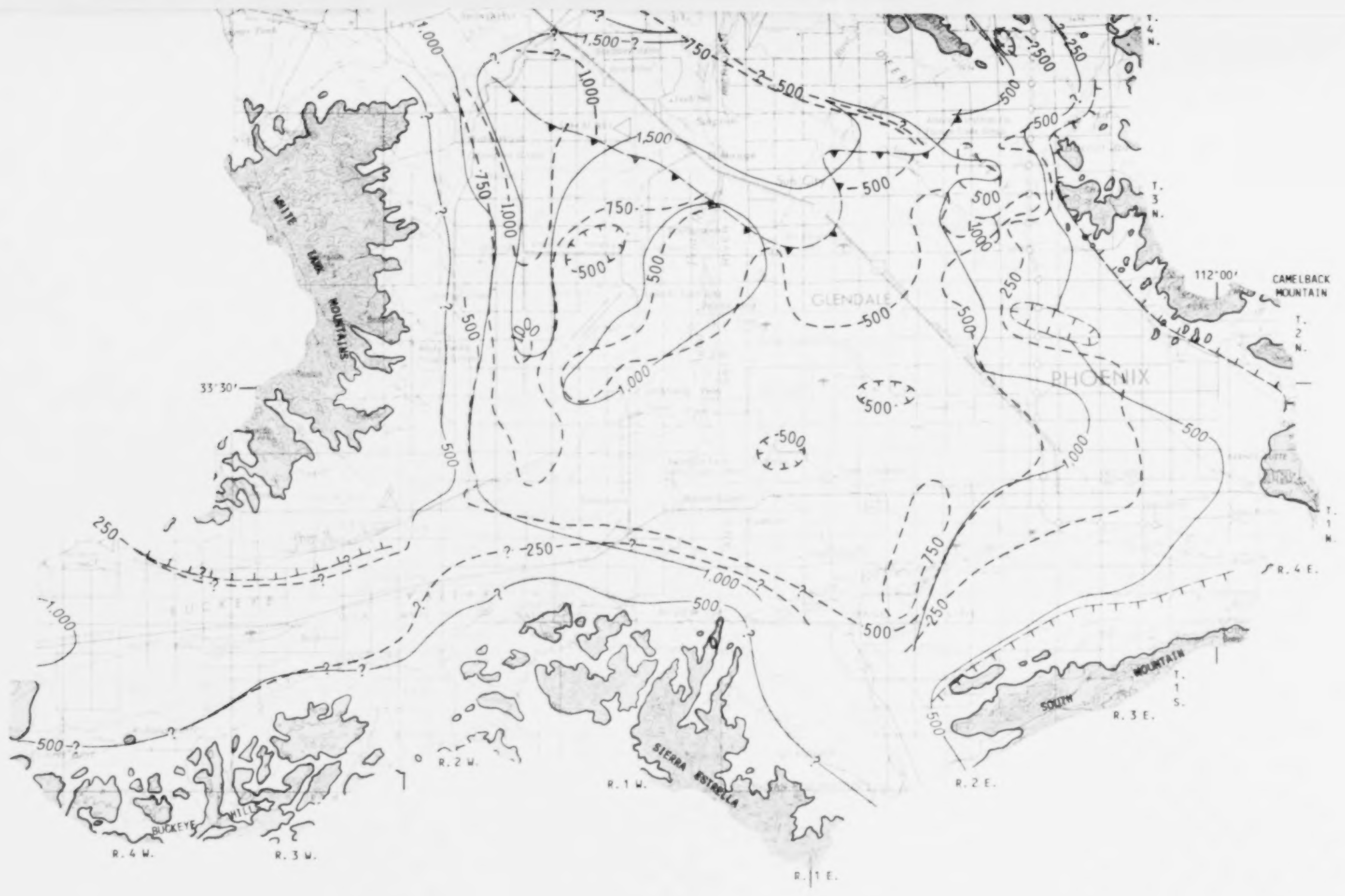

Figure 8.--Depth to the base and thickness of the upper part of the lower unit.

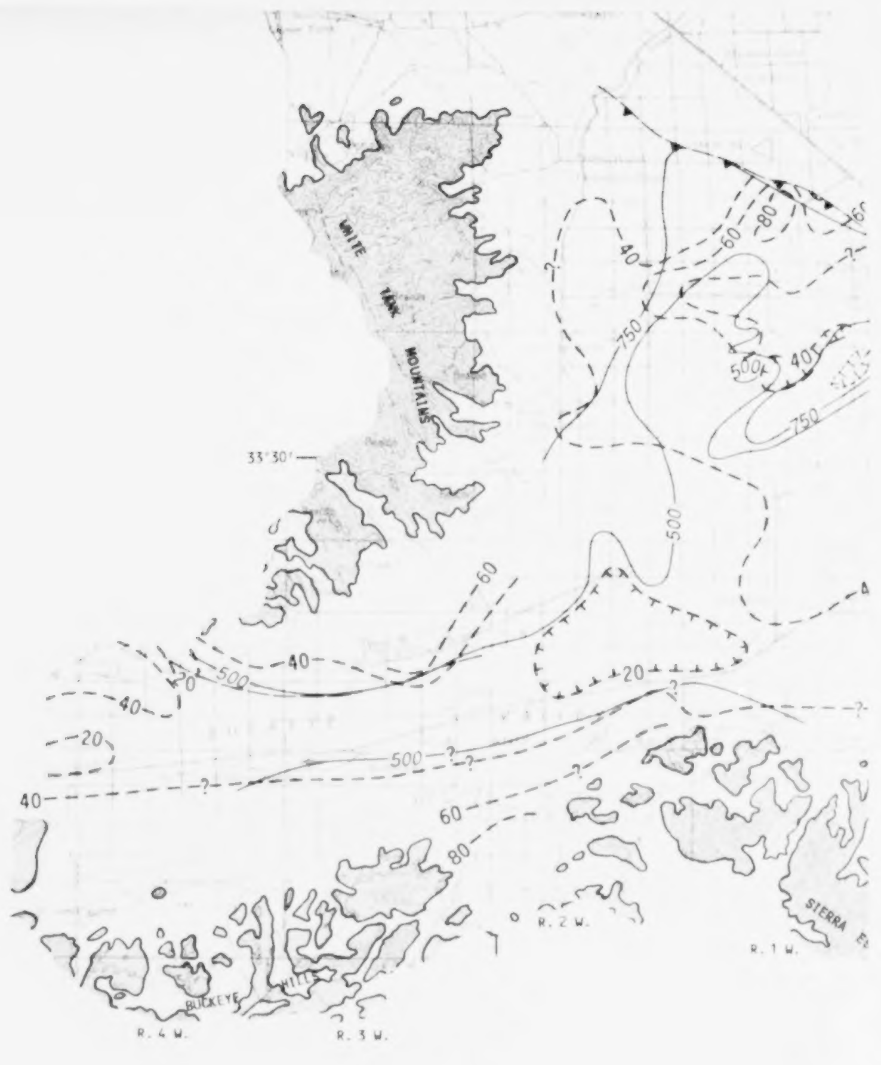

Figure 9.--Altitude of the base and perce

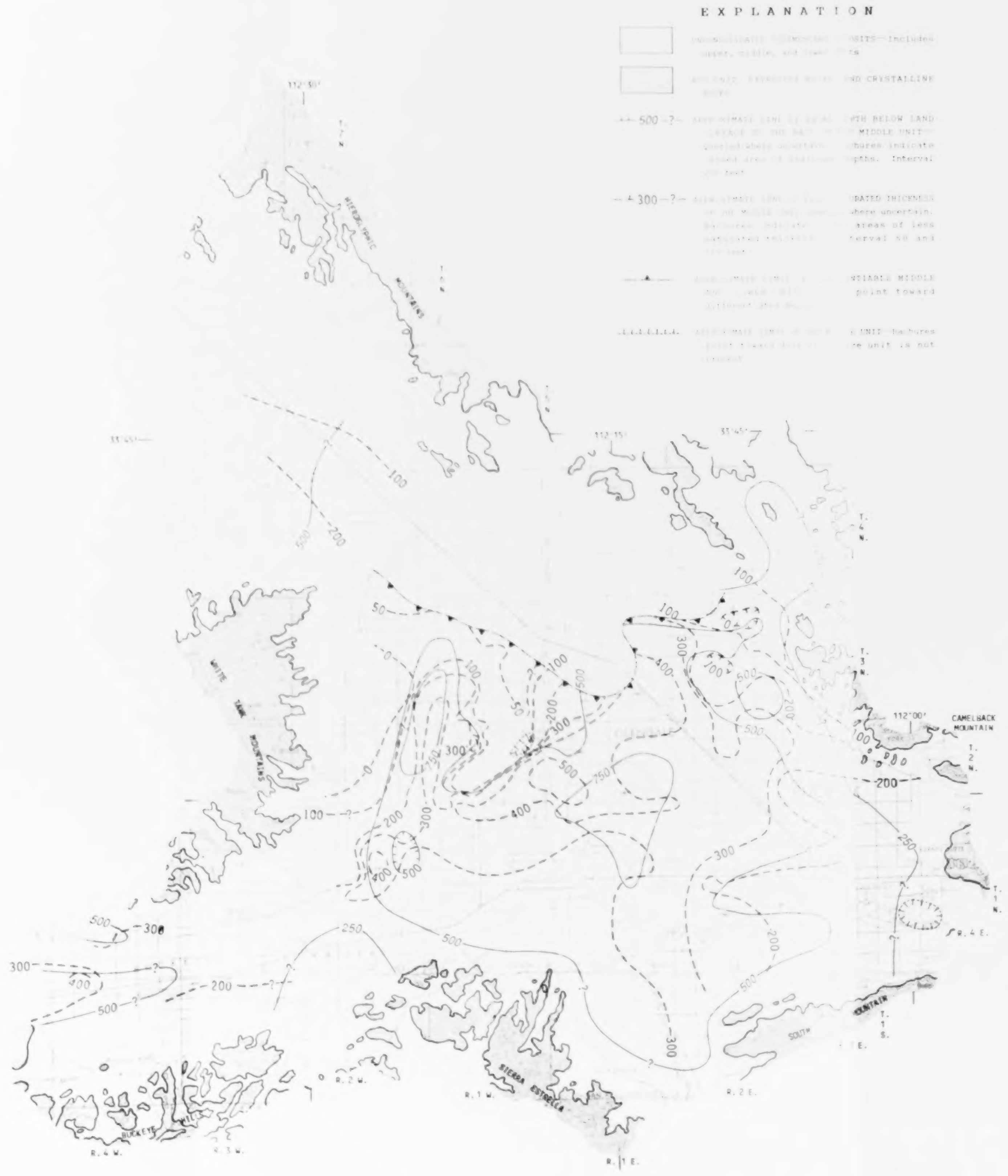

Figure 10.--Depth to the base and saturated thickness of the middle unit.

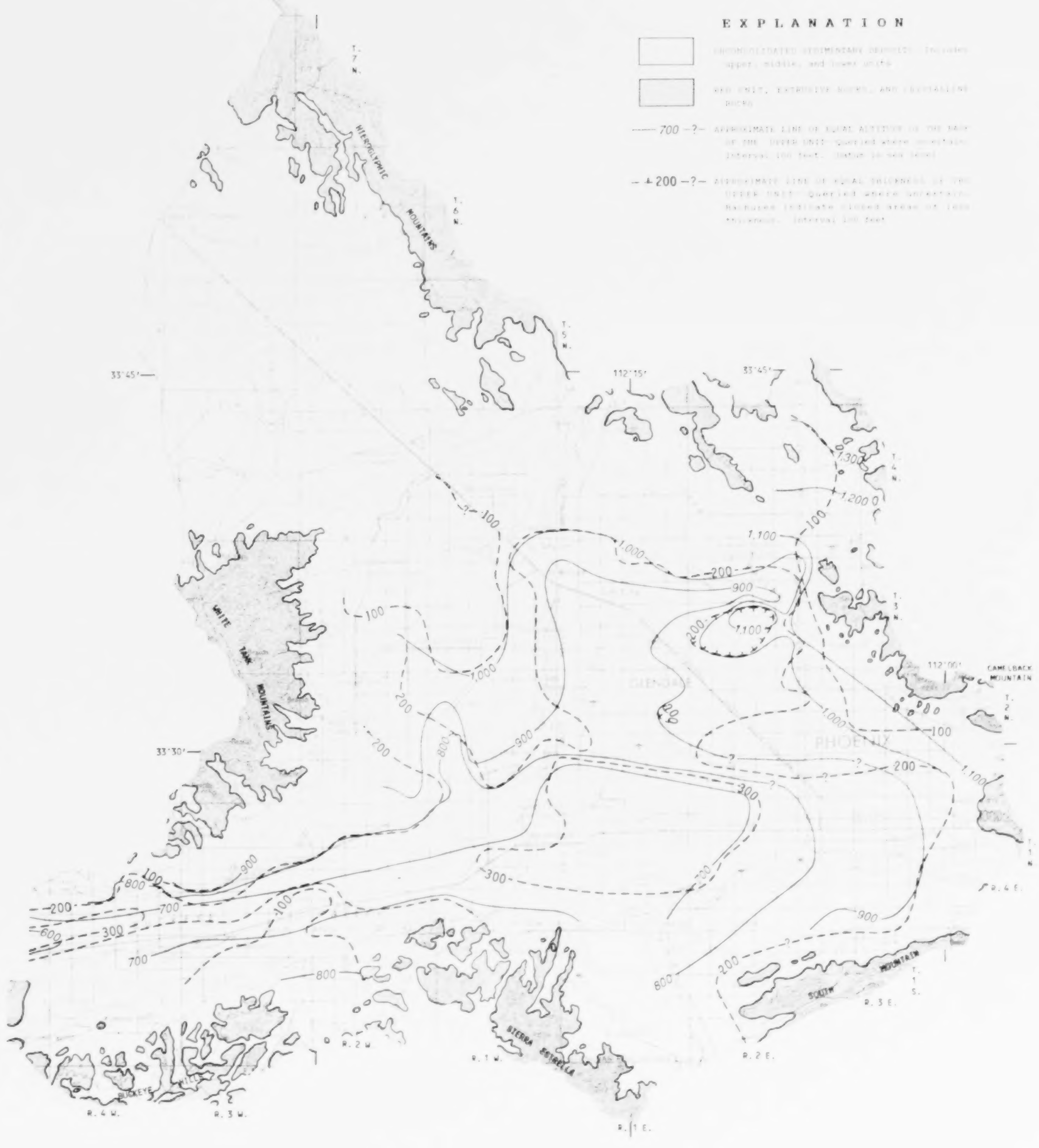

Figure 11.--Altitude of the base and thickness of the upper unit.

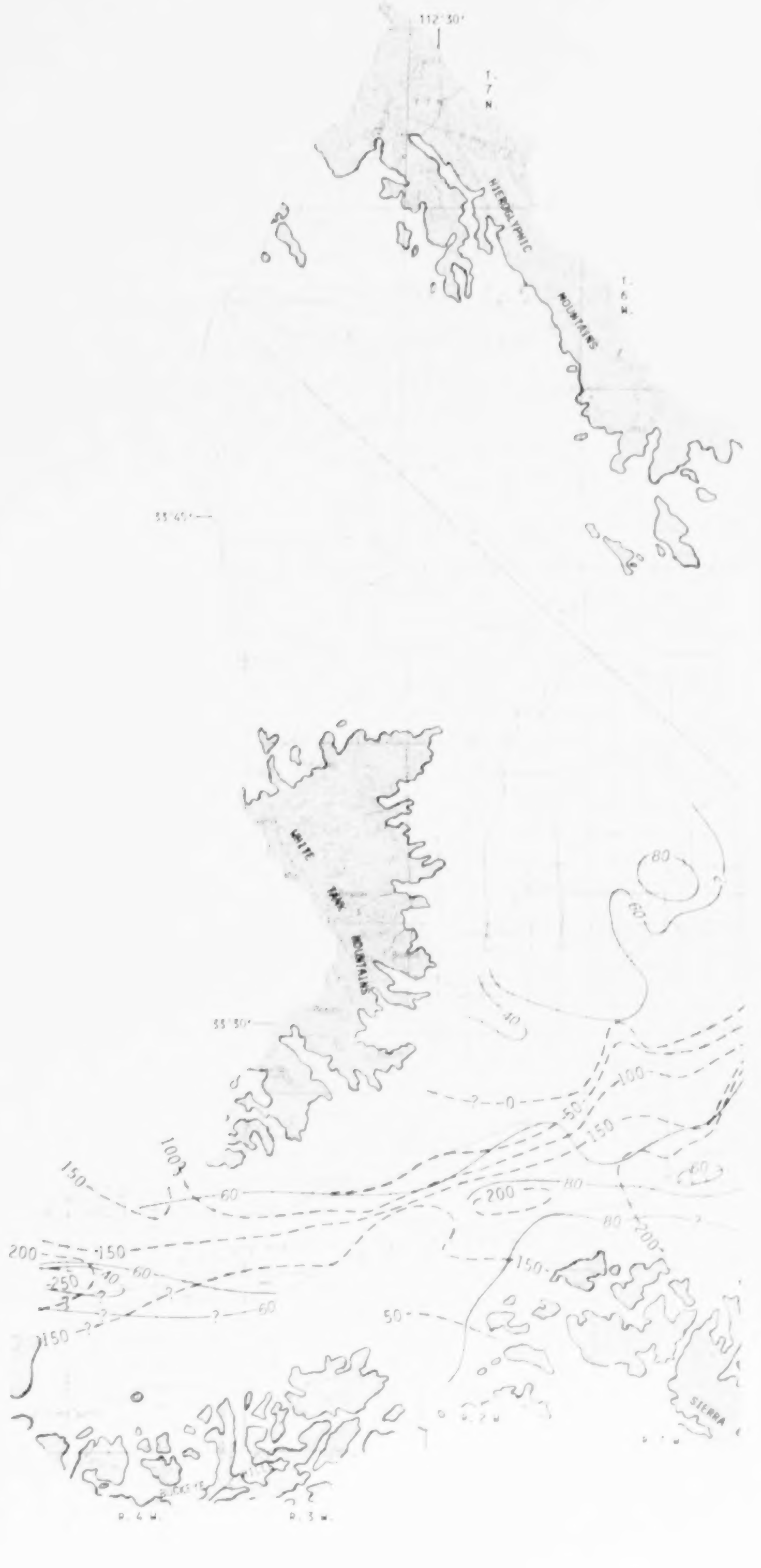

Figure 12.--Percent sand and gravel and s

Base from U.S. Geological Survey 1:250,000
Mesa, 1954-69 and
Phoenix, 1954-69

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HYDROGEOLOGY OF THE WESTERN PART OF THE SALT RIVER VALLEY AREA, MARICOPA COUNTY, ARIZONA

By James G. Brown and D. R. Pool
1989

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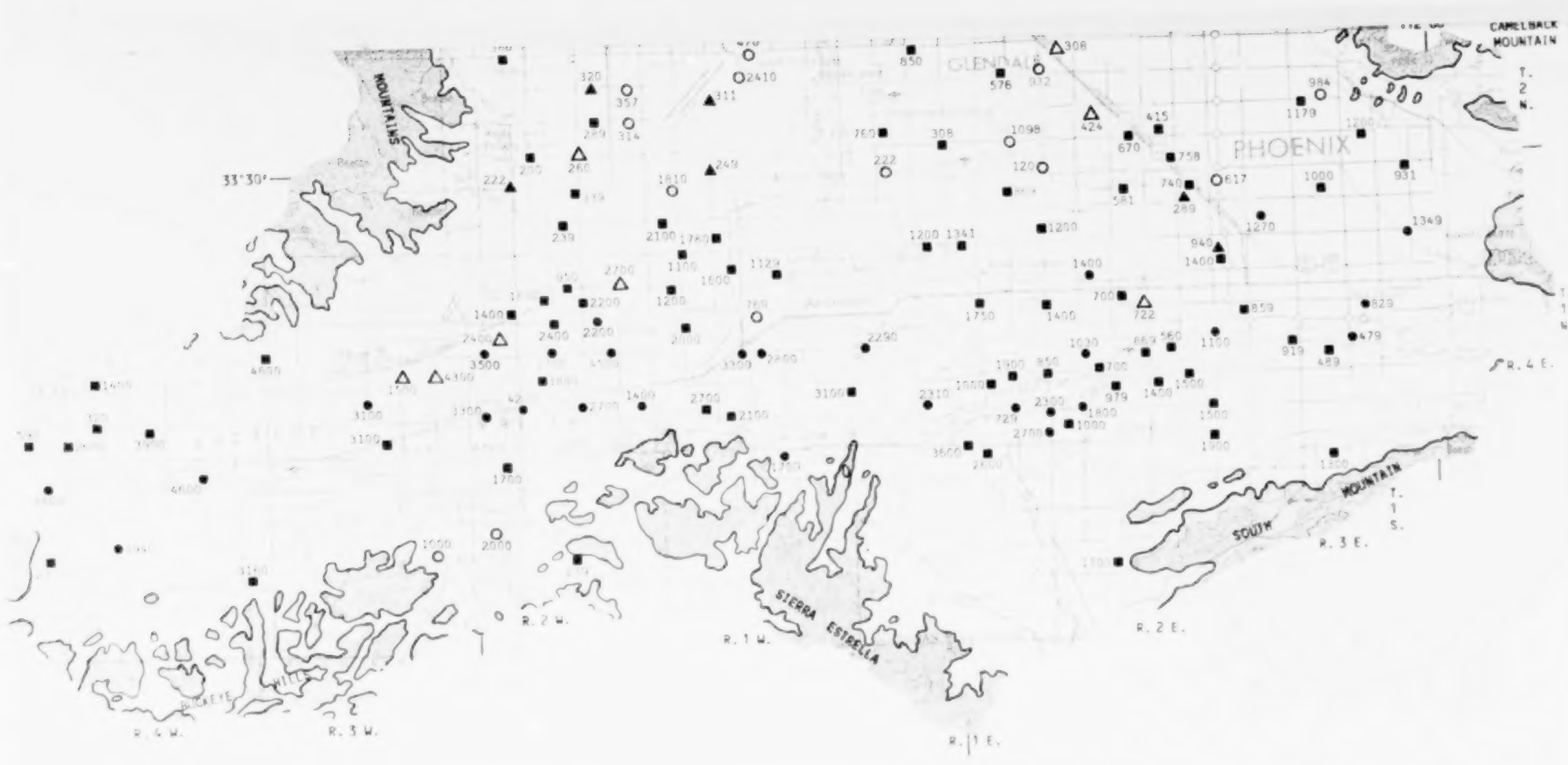


Figure 13.--Dissolved-solids concentrations in water from selected wells, 1980-85.

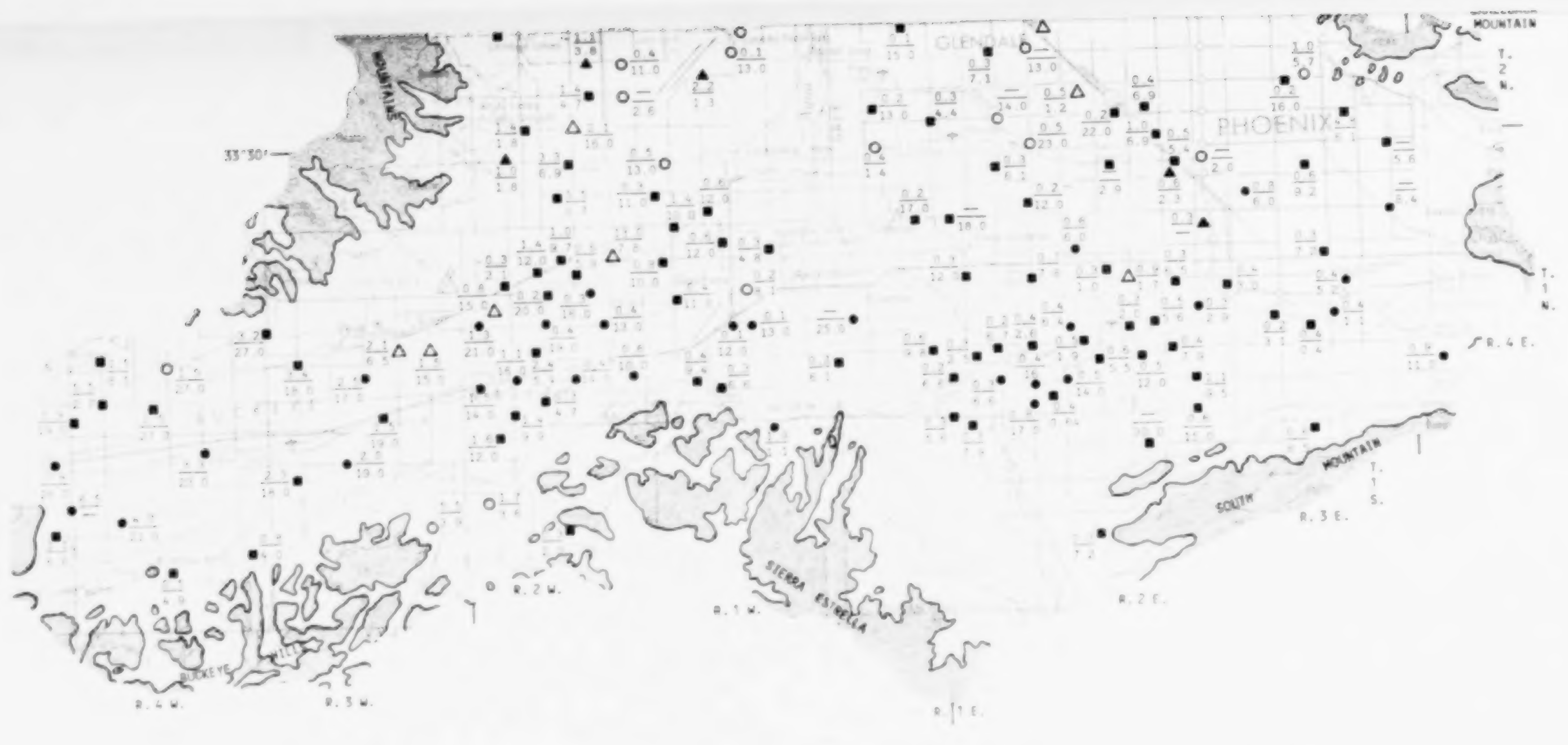


Figure 14.--Fluoride and nitrate concentrations in water from selected wells, 1980-85.

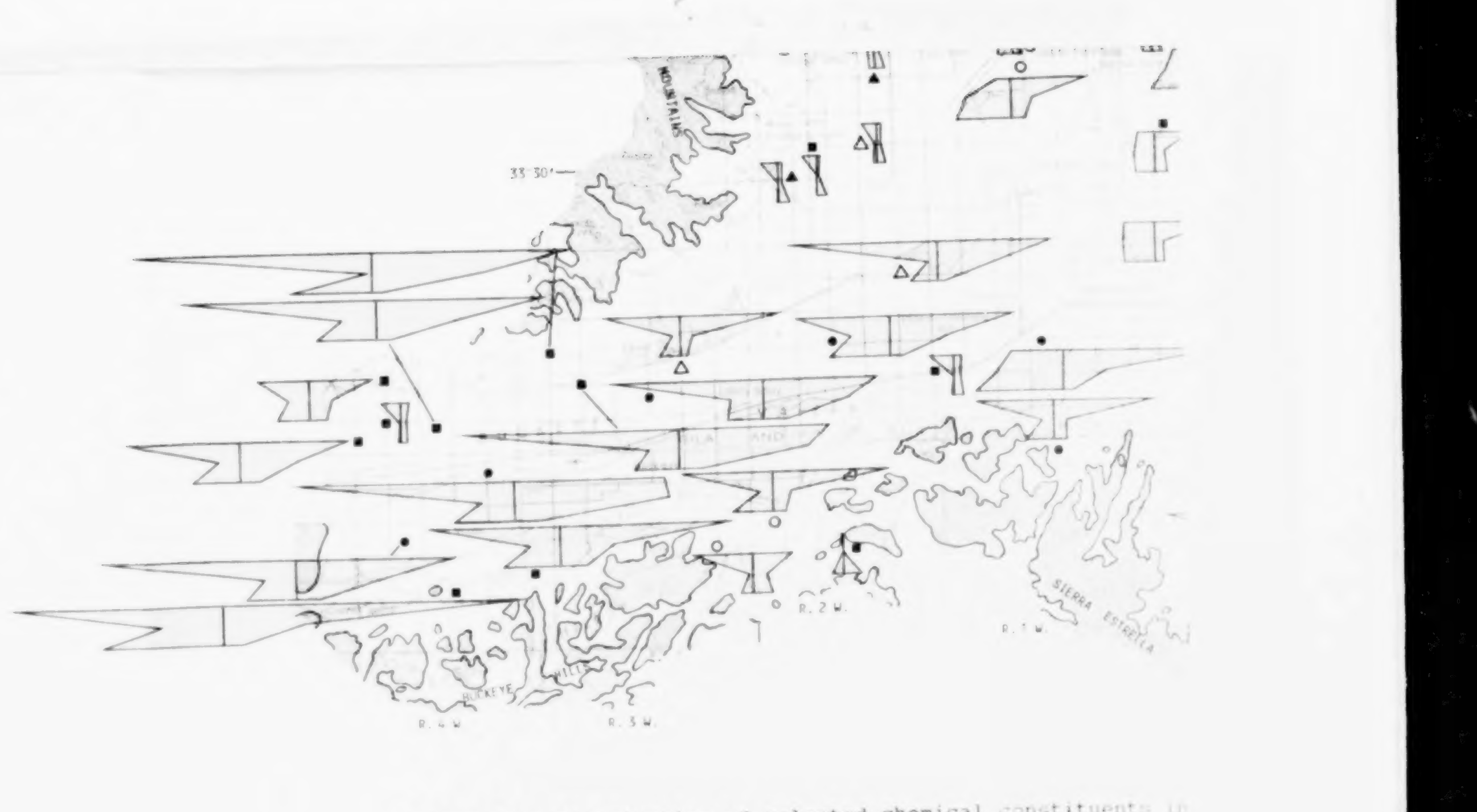
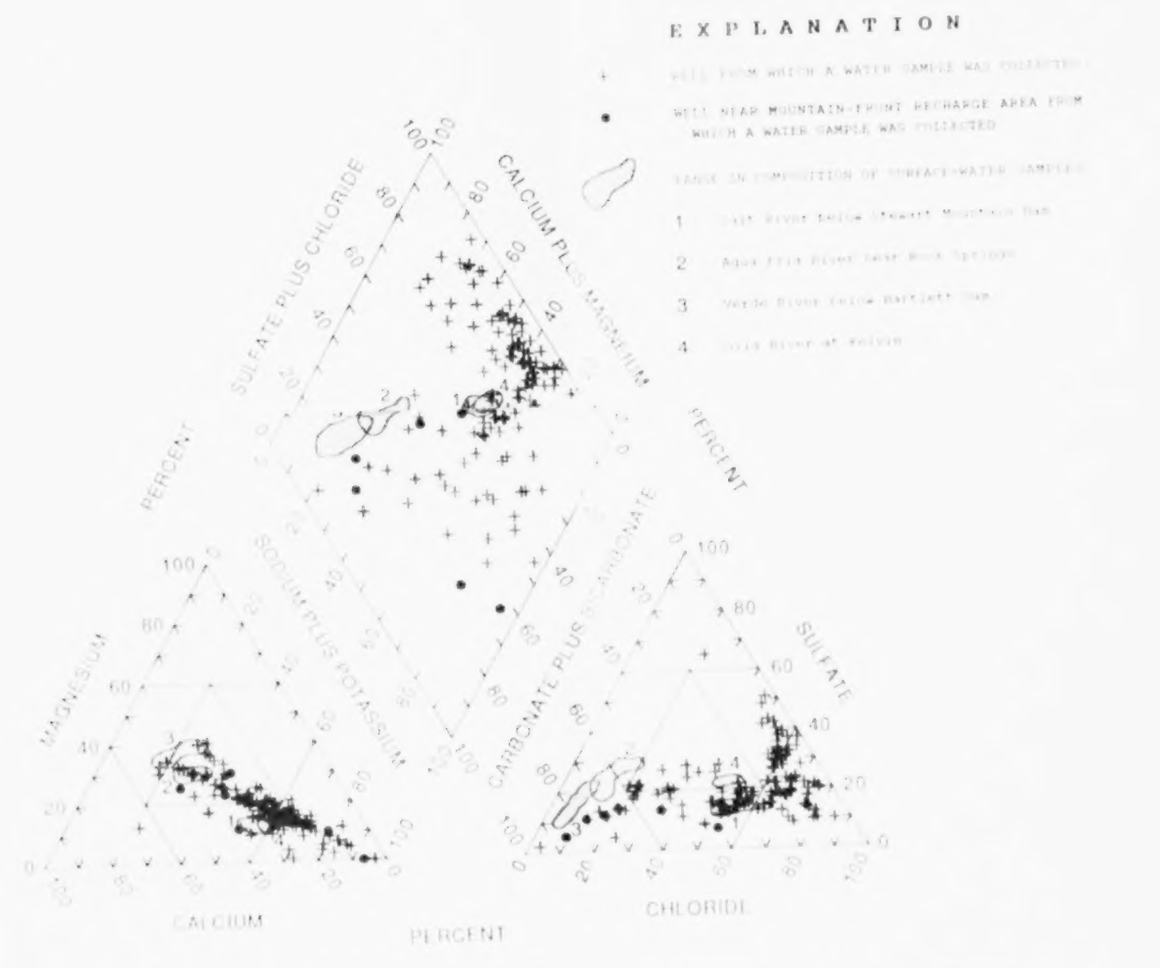


Figure 15.--Distribution of selected chemical constituents in



igure 16.--Percentages of chemical constituents in ground water and surface water.

WATER QUALITY

Ground-water quality in the study area is the result of the natural geochemical processes that occur in the subsurface and, to a lesser extent, the effects of human activities. [illegible] quality in the western part of the Salt River Valley [illegible] varies greatly. Dissolved-solids concentrations in ground water may exceed 4,000 mg/L adjacent to the Gila River (fig. 13) and exceed 10,000 mg/L at depth near the Luke salt body. Water in the other parts of the valley generally is suitable for domestic supply but locally may exceed drinking-water standards for fluoride or nitrate (fig. 14; table 2). Principal ions dissolved in the ground water are sodium, calcium, chloride, and bicarbonate. Waters are commonly classified on the basis of percentage concentrations of the major cations and anions in milliequivalents per liter. Classifying water as a sodium chloride type, for example, indicates that more than 50 percent of the dissolved cations are sodium and more than 50 percent of the dissolved anions are chloride. Water in which no ion is dominant is referred to as mixed.

Chemical Evolution of the Ground Water

Chemical evolution of ground water in alluvial basins is the result of a complex series of geochemical reactions, which in the study area are complicated by both the heterogeneity of the system and the effects of human activities. Natural factors include mineralogy, such as the presence of evaporite deposits; the order in which various mineral assemblages are encountered as ground water flows through the aquifer (Freeze and Cherry, 1979); and influxes of large quantities of surface-water recharge at infrequent intervals along the major drainages. Human activities that may affect the quality and movement of the ground water include deep percolation of excess irrigation water, seepage of sewage effluent, urban runoff, and changes in the direction of ground-water flow because of pumpage.

Near mountain-front recharge areas, ground water tends to be low in dissolved solids and is either a mixed or mixed bicarbonate type (figs. 13, 16). Recharge from major streams tends to be higher in dissolved solids than recharge along mountain fronts and is more variable in composition. Ground water in Buckeye Valley typically is high in dissolved solids and is consistently a sodium chloride water (figs. 13, 16). The trilinear diagram in figure 16 shows the variation in chemical types in ground water and surface water in the study area and illustrates changes in chemical nature as the ground water moves through the subsurface.

The linear trend in the cation diagram shows the tendency for ground water to become more sodium rich through time but is complicated by the presence of recharge waters of different quality. Water from the Verde and Agua Fria Rivers plots at one end of the cluster of points, and water from the Salt River plots near the center of the cluster. Although most sample points from wells near mountain-front recharge areas plot near the center of the diagram, the presence of several points near the sodium apex suggests that, under certain conditions, the transition to a sodium-rich water may occur relatively soon after infiltration and need not be accompanied by a significant increase in dissolved solids.

The trend of data on the anion diagram (fig. 16) indicates a transition from a bicarbonate water to one rich in chloride. A large cluster of points along the right side of the triangle represents samples that contain more than 60 percent chloride, less than 15 percent bicarbonate, and sulfate percentages between 15 and 35. Most of these samples are from sites in the Buckeye Valley and probably represent water whose chemistry has been affected by irrigation return flow.

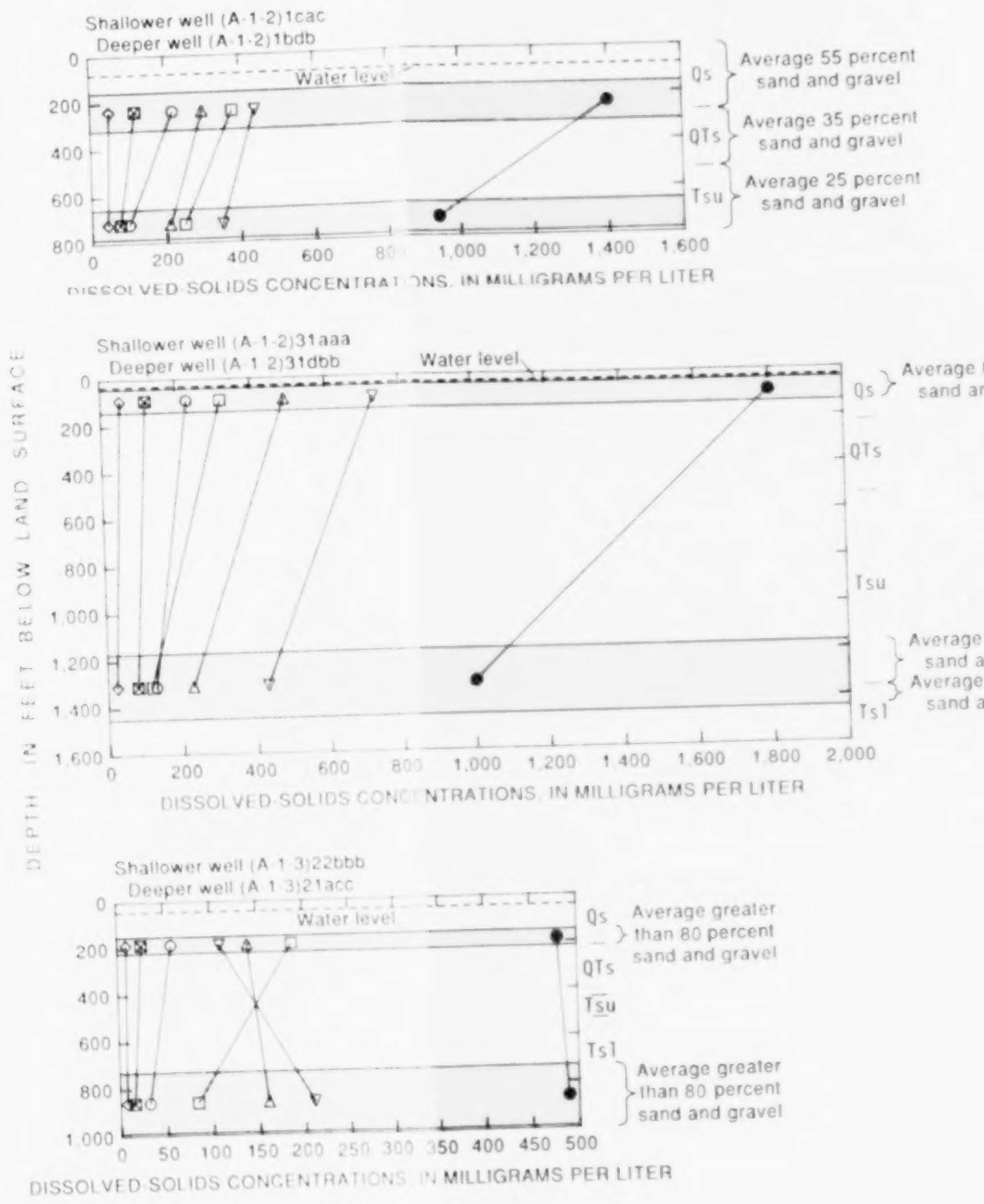


Table 2.--*Chemical analyses of water from selected wells*

[Ft, feet; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25° Celsius; <, less than; ----, indicates no data]

LOCAL IDENTIFIER	WELL DEPTH (FT)	DATE	TEMPERATURE WATER (°C)	PH (STANDARD UNITS)	ALKALINITY LAB (mg/L as CaCO3)	CALCIUM DISSOLVED (mg/L as Ca)	MAGNESIUM DISSOLVED (mg/L as Mg)	POTASSIUM DISSOLVED (mg/L as K)	SODIUM DISSOLVED (mg/L as Na)	CHLORIDE DISSOLVED (mg/L as Cl)	SULFATE DISSOLVED (mg/L as SO4)	FLUORIDE DISSOLVED (mg/L as F)	NITROGEN, NO2+NO3 DISSOLVED (mg/L as N)	SILICA, DISSOLVED (mg/L as SiO2)	CHROMIUM, HEXAVALENT, DISSOLVED (µg/L as Cr)	ARSENIC DISSOLVED (µg/L as As)	MANGANESE, DISSOLVED (µg/L as Mn)	SELENIUM, DISSOLVED (µg/L as Se)	SPECIFIC CONDUCTANCE (µS/cm)	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (mg/L)
A-01-01 36AAD	156	07-21-83	27.5	7.20	369	160	72	6.8	570	980	500	[illegible]	16.0	27	<1	---	<10	---	3,920	2,300
A-01-02 08BAA1	284	07-24-84	23.5	7.60	428	76	40	4.6	410	430	[illegible]	[illegible]	6.00	31	<1	8	580	2	2,410	1,400
A-01-02 09CDB	1,600	08-03-84	32.0	7.90	110	58	36	4.9	140	310	59	[illegible]	1.00	21	2	5	2	<1	1,330	700
A-01-02 35DDD	230	07-26-84	24.5	7.30	250	130	48	4.8	500	640	420	[illegible]	15.0	36	<1	6	<10	9	3,160	1,900
A-01-03 15ABC	208	06-27-85	24.0	7.40	344	72	27	5.4	200	210	35	[illegible]	5.20	26	<1	6	<1	<1	1,440	830
A-01-04 30DDD	120	07-27-84	23.5	7.40	328	120	55	7.0	400	570	200	[illegible]	11.0	37	<1	8	20	5	2,760	1,600
A-02-01 17CAB2	720	07-21-84	28.5	7.50	140	90	60	5.5	88	310	89	[illegible]	13.0	23	<1	2	3	2	1,440	760
A-02-02 01AAD	620	06-19-85	27.0	7.60	---			---					-----	---	---	---	----	--	1,060	----
A-02-02 26CDB	950	06-24-85	33.5	8.50	97	14	1.6	2.9	94	78	18	[illegible]	2.30	21	31	5	1	<1	530	290
A-02-03 28CAA	482	07-02-85	26.0	7.60	241	76	45	4.2	250	300	140	[illegible]	9.20	33	2	5	<1	5	1,690	1,000
A-03-01 27CCC	453	07-19-84	23.5	7.20	205	150	61	4.0	81	300	120	[illegible]	11.0	31	<1	1	3	2	1,590	850
A-03-02 20AAA2	1,200	08-11-81		----	151	83	55	8.0	86	230	120	[illegible]	47.0	---	--	--			----	720
A-03-02 24BAB2	1,430	08-08-83	32.0	7.90	---	45	28	---	53	----	----		-----	30	33	6	2	--	720	-----
A-04-01 05ACD	600	08-24-85	23.0	7.60	207	47	15	2.4	31	24	22	[illegible]	1.80	34	<1	--	2	--	475	300
A-04-01 34ABA	1,190	06-25-85	28.0	7.70	128	47	23	3.8	46	60	43	[illegible]	11.0	34	6	3	<1	1	650	340
A-04-02 11ADB	900	07-30-85	28.0	7.60	173	33	17	2.9	42	13	14	[illegible]	4.50	42	1	--	8	--	438	270
B-01-01 10CCD	405	08-11-80	26.0	7.00	---	130	58	4.8	80	310	110	[illegible]	8.10	26	8	4	<1	3	1,380	760
B-01-02 01CCC	1,900	06-12-85	42.0	7.70	73	130	28	4.5	750	910	640	[illegible]	7.80	27	<1	74	<10	3	4,110	2,600
B-01-02 17CAA	1,200	06-27-85	27.0	7.30	179	220	100	6.9	480	810	600	[illegible]	15.0	25	5	1	20	15	3,710	2,400
B-01-03 27CBB	178	06-27-85	24.0	7.30	267	170	92	6.2	810	910	920	[illegible]	17.0	24	3	4	<10	18	4,750	3,100
B-01-04 24AAA	402	07-12-84	31.5	7.70	49	390	9.5	16	1,200	1,600	1,000	[illegible]	27.0	35	<1	18	20	22	7,000	4,600
B-01-04 32BBB2	1,580	06-13-85	37.0	8.90	70	8.0	2.8	1.5	99	84	80	[illegible]	2.70	22	17	17	<1	3	540	320
B-02-01 03BBA2	386	07-05-83	25.5	7.50	106	71	32	3.1	44	180	59	[illegible]	5.80	28	<1	---	<3	--	880	470
B-02-01 19DBB2	627	08-16-83	28.0	7.60	96	71	36	4.5	180	300	160	[illegible]	7.20	19	3	---	2		1,550	850
B-02-02 05AAB	747	07-05-83	30.0	7.60	128	47	8.9	4.3	74	120	20	[illegible]	1.80	25	<1	---	<2	---	715	380
B-02-02 11BBB	800	07-19-84	31.0	8.30	105	20	7.8	2.4	55	34	21	[illegible]	3.80	21	2	.10	<1	1	430	220
B-02-02 20DDD	500	08-21-84	32.0	8.20	129	8.8	3.6	3.0	63	22	21	[illegible]	1.80	13	2	11	2	<1	380	210
B-03-01 03ABB	1,000	06-29-84	31.0	7.90	124	31	12	3.2	90	66	31	[illegible]	6.50	25	15	9	<1	<1	670	370
B-03-01 27AAB	1,085	06-29-84	35.0	8.40	128	8.7	3.4	2.1	85	33	32	[illegible]	2.00	20	49	25	<1	<1	425	260
B-03-01 29BBB	1,140	06-29-84	31.0	8.00	115	28	12	3.1	75	42	58	[illegible]	5.40	20	33	5	<1	<1	610	320
B-03-02 14BCB	1,400	06-28-84	42.5	9.10	102	2.4	0.07	1.3	78	25	29	[illegible]	0.540	23	55	34	<1	<1	400	210
B-04-01 29ABB	900	08-01-84	32.0	7.90	143	26	8.6	2.8	74	38	31	[illegible]	1.20	27	<1	8	2	<1	528	310
B-04-02 10CDA	480	08-02-84	27.0	8.10	117	21	8.5	2.6	39	13	22	[illegible]	0.750	17	3	1	4	<1	338	250
B-05-03 15AAA	600	07-18-84	26.5	7.50	183	45	14	2.5	37	22	25	[illegible]	0.600	27	<1	1	3	<1	475	290
B-05-03 33BDA	----	08-04-83	24.0	7.70	165	36	12	2.3	32	18	23	[illegible]	0.780	23	--	--	7	--	405	250
B-06-02 31BDD	910	08-03-83	28.0	7.70	96	99	16	4.5	180	110	480	[illegible]	0.720	30	<1	7	12	--	1,390	960
B-06-03 05ADC	90	08-03-83	25.0	7.70	239	30	8.8	1.6	86	27	23	[illegible]	3.20	34	<1	24	<3	--	575	360
B-06-03 33DCB	800	07-31-85	31.0	7.60	138	39	15	3.0	87	60	87	[illegible]	1.10	32	4	--	3	--	660	410
C-01-01 03AAD	101	08-02-84	27.0	7.70	145	140	37	6.3	420	840	140	[illegible]	1.10	30	<1	2	<10	<1	3,010	1,700
C-01-02 18ACA	180	07-17-84	25.5	7.40	153	190	38	8.4	470	950	200	[illegible]	3.60	27	<1	1	<10	1	3,500	2,000
C-01-02 22BBB	300	07-28-83	25.0	7.40	192	50	5.8	1.7	18	4.2	4.1	[illegible]	2.00	41	<1	--	<1	--	375	240
C-01-03 04CDD	110	07-13-84	22.0	7.20	291	230	100	5.6	870	1,200	730	[illegible]	19.0	42	<1	8	<10	10	5,600	3,400
C-01-03 14DDD2	190	05-31-83	26.5	7.40	230	58	7.5	4.9	300	310	150	[illegible]	3.90	29	<1	6	<1	--	1,900	1,000
C-01-04 17DCB	114	07-11-84	22.5	7.20	305	230	89	8.3	990	1,300	990	[illegible]	21.0	42	<1	12	<10	13	6,100	3,800
C-01-04 24CAD	400	07-11-84	22.0	7.20	300	260	88	8.5	700	1,300	570	[illegible]	4.00	32	<1	3	10	1	5,050	3,100
D-01-02 07DCC	520	07-31-84	25.0	7.30	215	180	74	6.8	470	930	270	[illegible]	5.20	35	<1	8	<10	3	3,650	2,100
D-01-02 20ADD	300	07-11-83	27.0	7.40	159	180	60	8.7	350	780	200	[illegible]	7.20	27	10	3	6	--	3,070	1,700
D-01-03 04ACC	391	07-11-83	24.0	7.40	322	51	23	3.5	380	440	170	[illegible]	8.50	25	<1	8	7	--	2,300	1,300

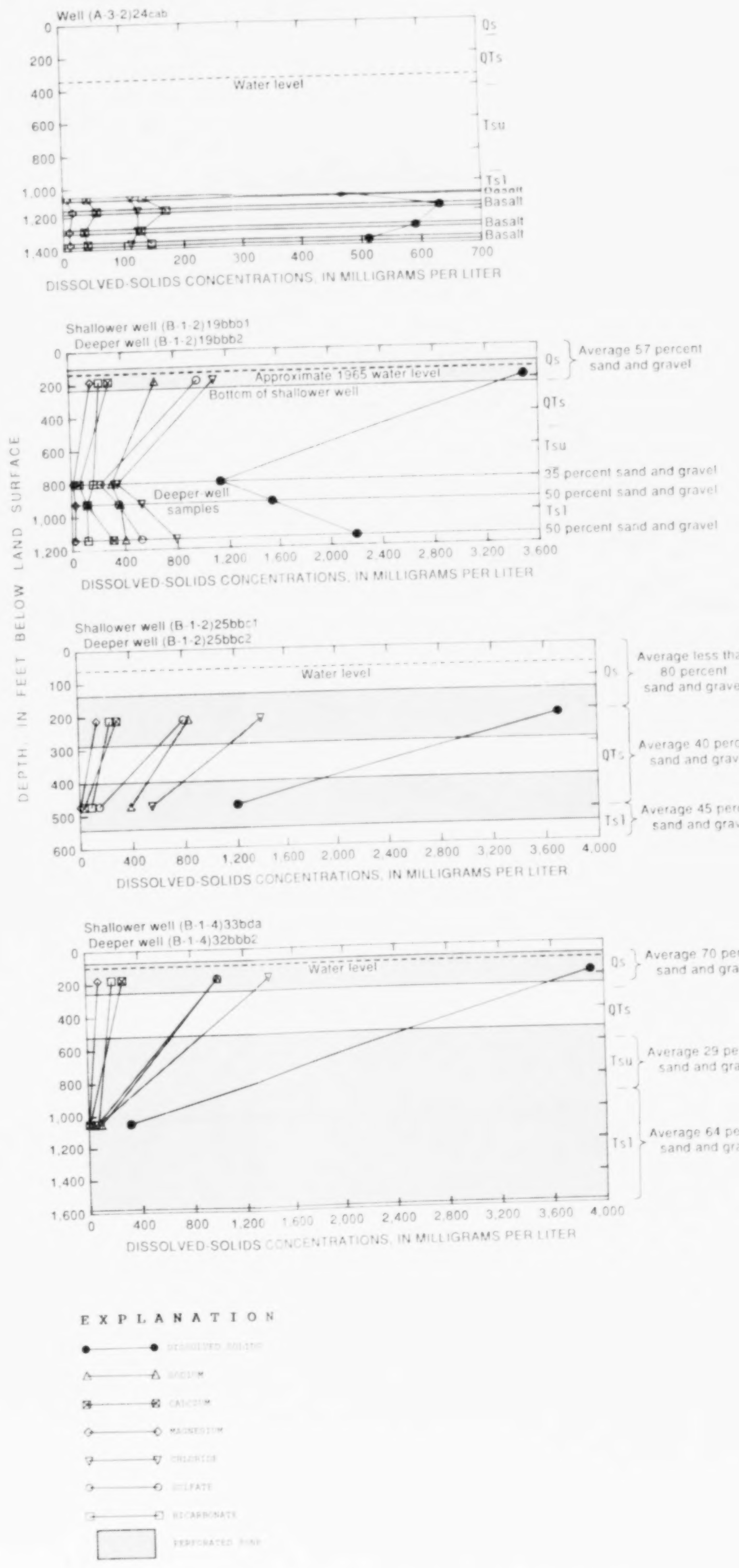


Figure 17.--Variation of selected dissolved constituents in ground water with depth.

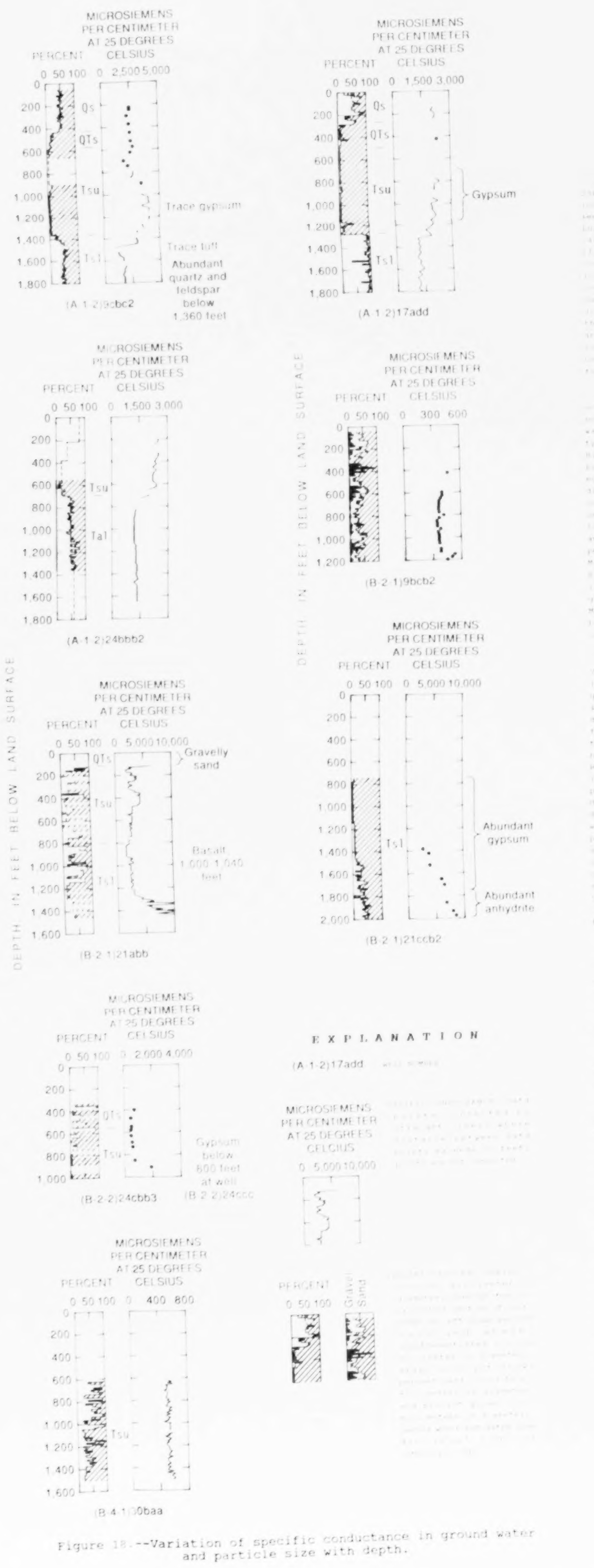


Figure 18.--Variation of specific conductance in ground water and particle size with depth.

Areal Distribution

[illegible]

Vertical Variation

[illegible]

5 0 5 10 MILES
5 0 5 10 KILOMETERS

TOPOGRAPHIC CONTOUR INTERVAL 200 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

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U.S. Geological Survey [illegible]
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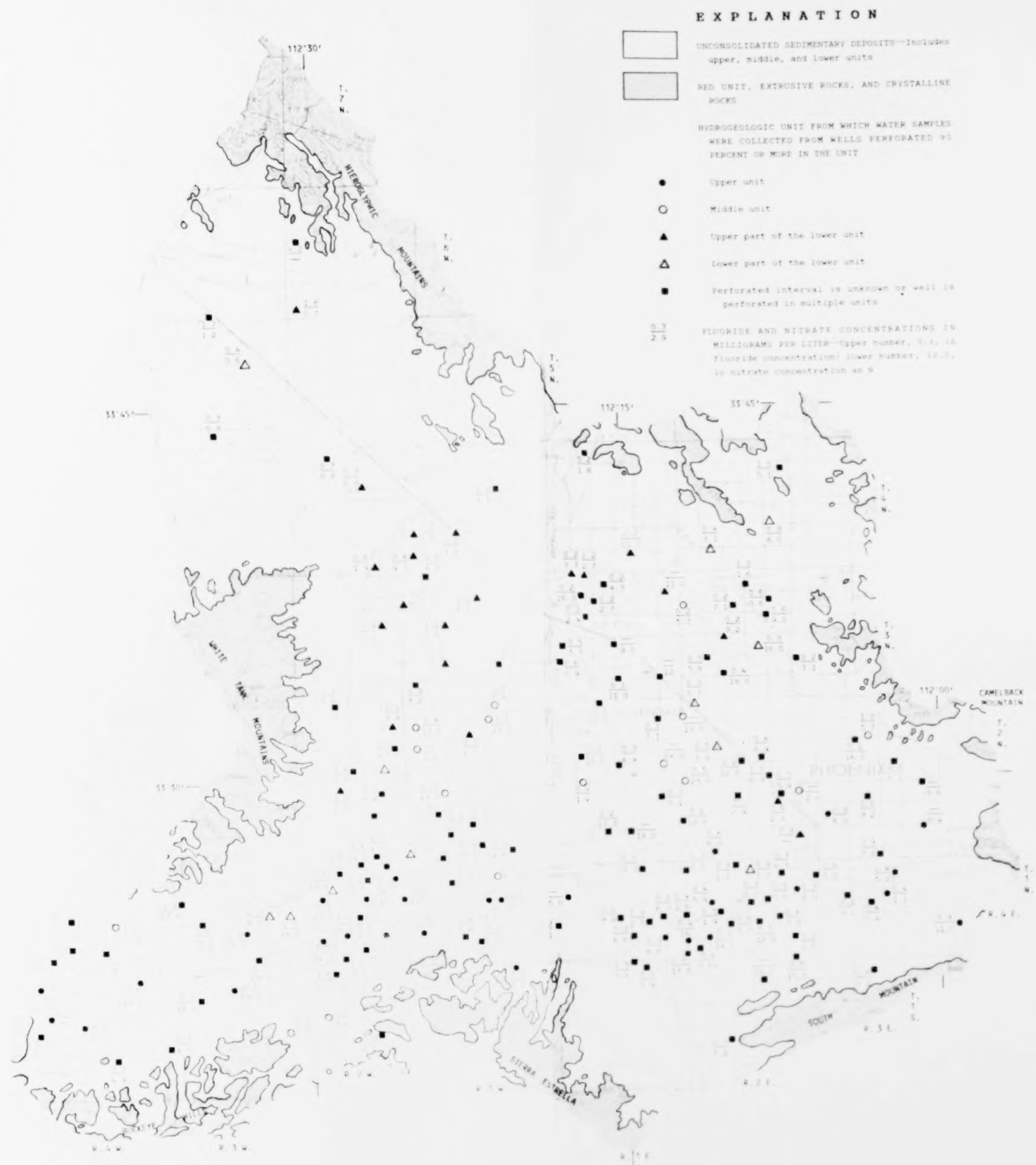
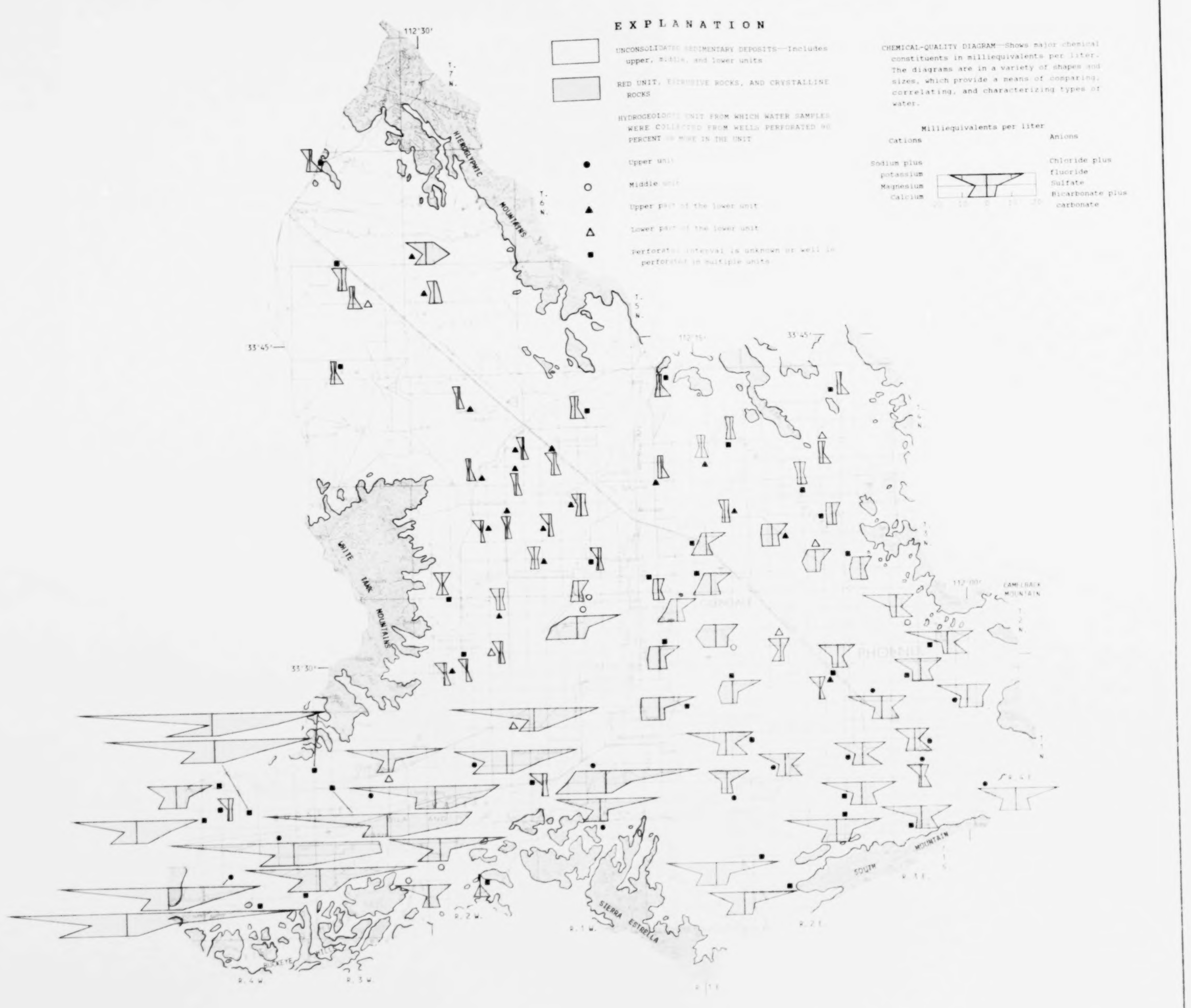

EXPLANATION
UNCONSOLIDATED SEDIMENTARY DEPOSITS—Includes upper, middle, and lower units
RED UNIT, EXTRUSIVE ROCKS, AND CRYSTALLINE ROCKS
HYDROGEOLOGIC UNIT FROM WHICH WATER SAMPLES WERE COLLECTED FROM WELLS PERFORATED 90 PERCENT OR MORE IN THE UNIT
● Upper unit
○ Middle unit
▲ Upper part of the lower unit
△ Lower part of the lower unit
■ Perforated interval is unknown or well is perforated in multiple units
0.3/2.9 FLUORIDE AND NITRATE CONCENTRATIONS IN MILLIGRAMS PER LITER—Upper number, 0.3, is fluoride concentration; lower number, 2.9, is nitrate concentration as N
112°30'
112°15'
33°45'
33°30'
T. 5 N.
T. 4 N.
CAMELBACK MOUNTAIN
WHITE TANK MOUNTAINS
SIERRA ESTRELLA
SOUTH MOUNTAIN

Figure 14.--Fluoride and nitrate concentrations in water from selected wells, 1980-85.


EXPLANATION
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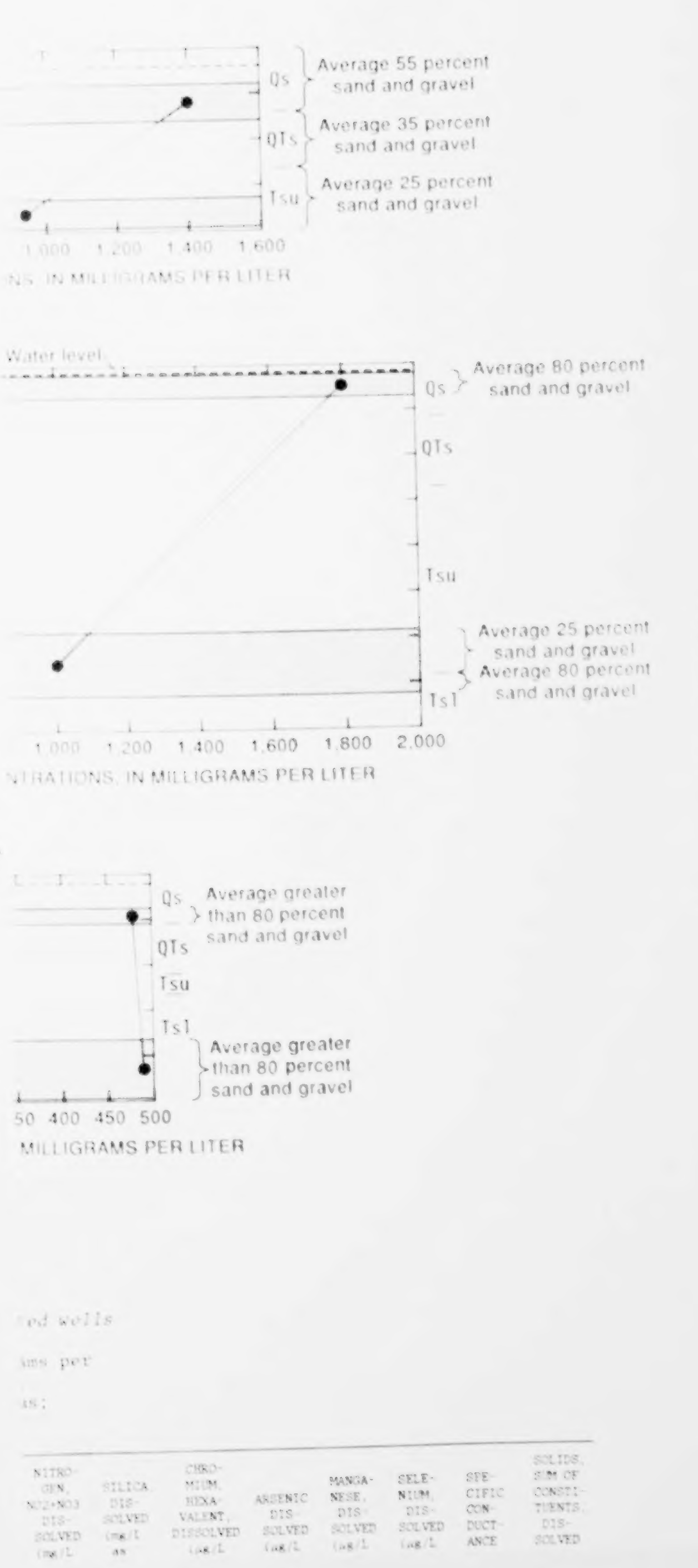
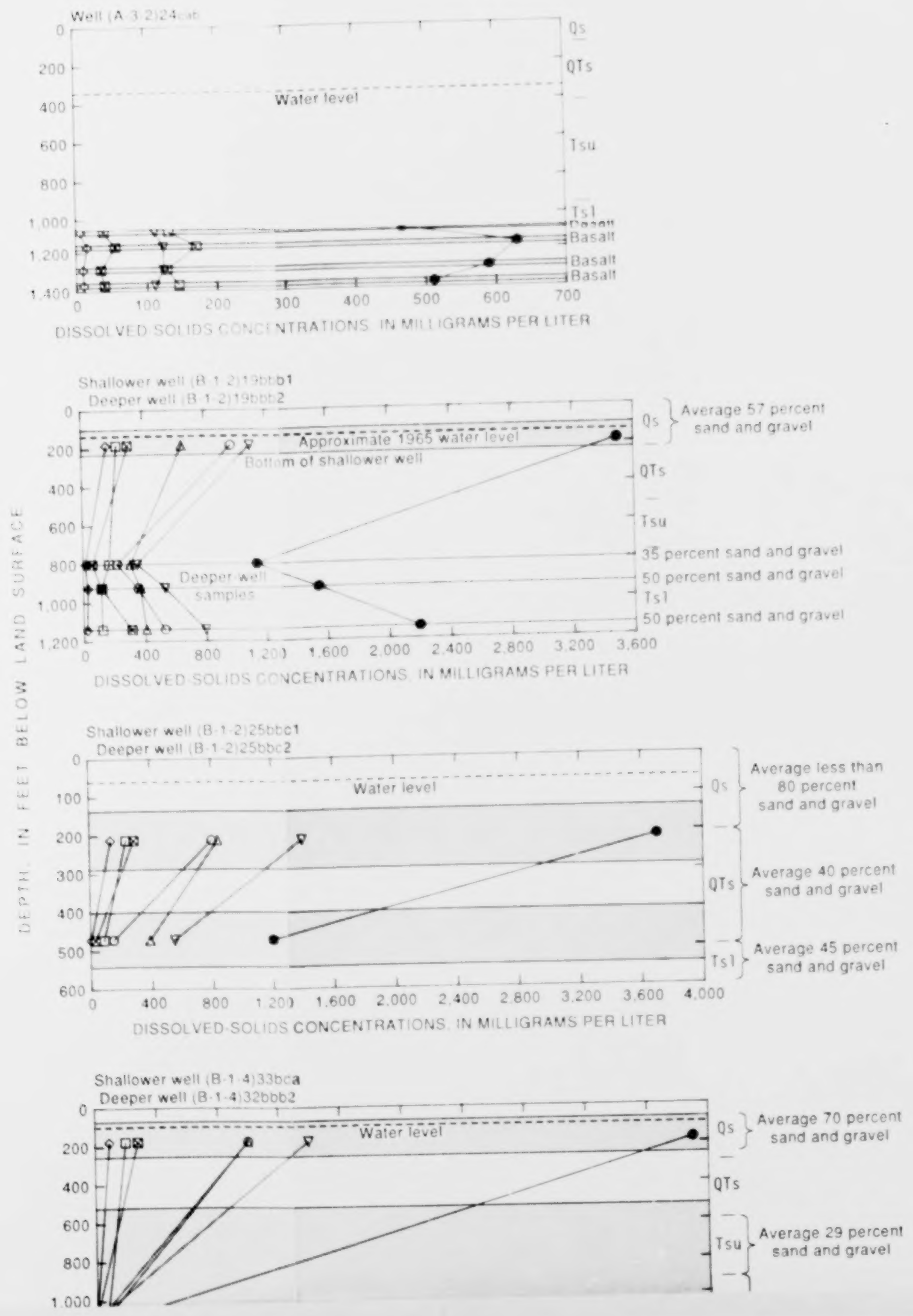
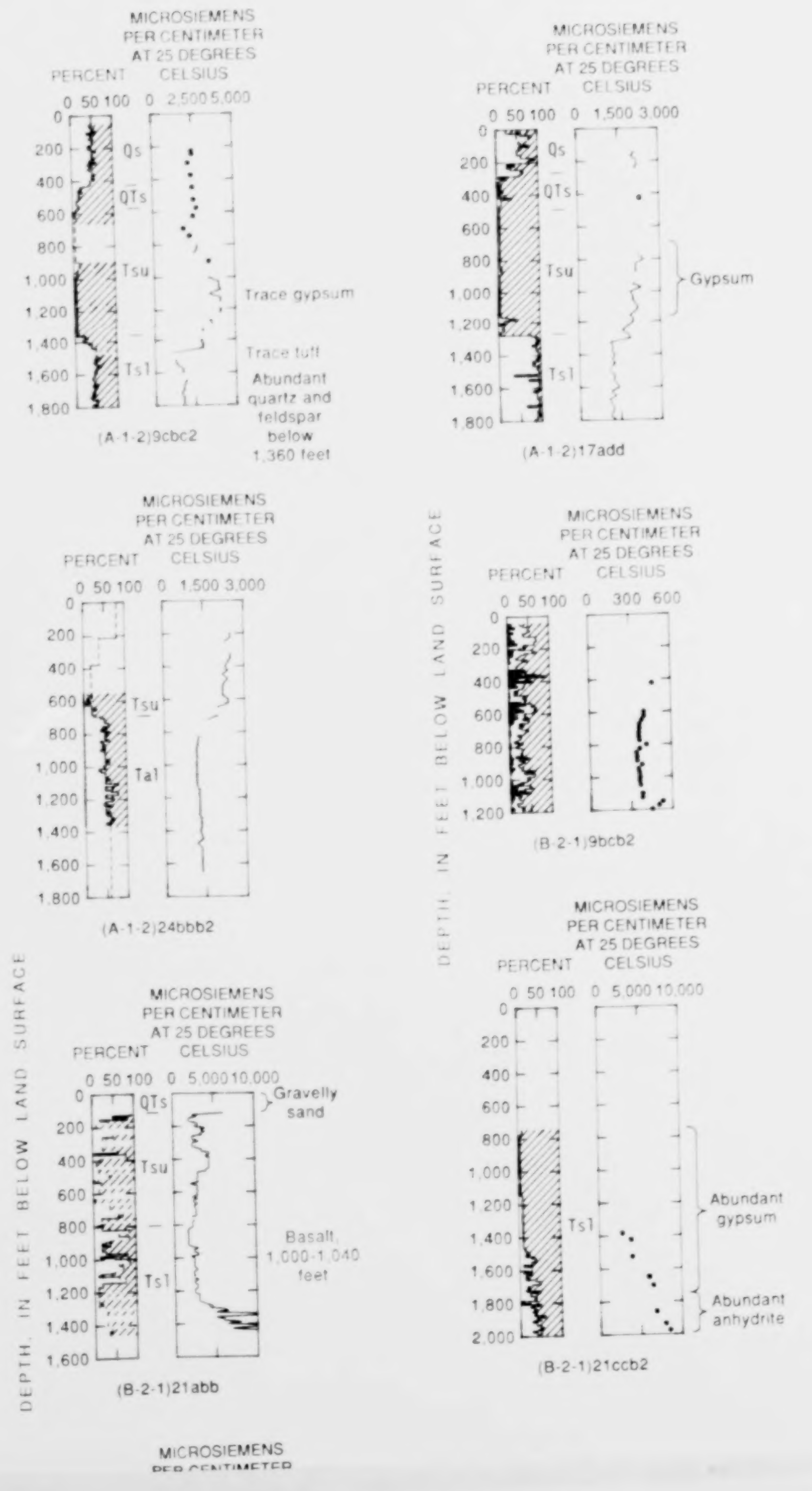
● Upper unit
○ Middle unit
▲ Upper part of the lower unit
△ Lower part of the lower unit
■ Perforated interval is unknown or well is perforated in multiple units
CHEMICAL-QUALITY DIAGRAM—Shows major chemical constituents in milliequivalents per liter. The diagrams are in a variety of shapes and sizes, which provide a means of comparing, correlating, and characterizing types of water.
Milliequivalents per liter
Cations
Anions
Sodium plus potassium
Magnesium
Calcium
Chloride plus fluoride
Sulfate
Bicarbonate plus carbonate
20 10 0 10 20
112°30'
112°15'
33°45'
33°30'
CAMELBACK MOUNTAIN
WHITE TANK MOUNTAINS
SIERRA ESTRELLA
SOUTH MOUNTAIN

Figure 15.--Distribution of selected chemical constituents in water from selected wells, 1980-85.







Areal Distribution of Water Quality

Dissolved-solids concentrations in ground water range from [illegible] to greater than 4,[illegible] mg/L (fig. [illegible]) and may exceed [illegible] mg/L near the Luke salt body. Ground water containing less than 500 mg/L dissolved solids is found west and north of Luke Air Force Base. The major cations are sodium and calcium; the major anions are bicarbonate and chloride (fig. 15). Near Luke Air Force Base, dissolved-solids concentrations vary greatly and range from less than 1,000 mg/L to more than [illegible] mg/L. These extremely large concentrations are related to the presence of halite in the Luke salt body and associated evaporites. Water containing dissolved-solids concentrations of more than 1,000 mg/L occurs throughout Buckeye Valley and southwest of Goodyear. In these areas, sodium and chloride are the dominant ions. Dissolved-solids concentrations exceeding [illegible] mg/L occur between Goodyear and Buckeye, although better-quality water may be found at depth in this area.

East of the Agua Fria River, water containing dissolved-solids concentrations of less than [illegible] mg/L occurs to the north of Sun City and in Deer Valley (fig. [illegible]). The ground water in this area ranges from a mixed to mixed bicarbonate type. Bicarbonate is the dominant anion east of the Hedgpeth Hills. North of Sun City, concentrations of chloride and bicarbonate in milliequivalents per liter are approximately equal. In the southern part of Deer Valley, water containing dissolved-solids concentrations between [illegible] and 1,[illegible] mg/L occurs in the brown mudstone of the upper part of the lower unit and in basalt flows and detritus of the lower part of the lower unit. The water is a mixed type but is somewhat anomalous in that magnesium concentrations in milliequivalents per liter are slightly higher than those of calcium or sodium. Magnesium in ground water is derived from ferromagnesian minerals, such as augite, hornblende, and biotite (Robertson, in press), all of which occur in varying amounts in the granitic and volcanic detritus in the basin fill. Montmorillonite is by far the most abundant clay mineral in basin-fill deposits (Robertson, in press), and also may be a source of magnesium.

Dissolved-solids concentrations in well water between Deer Valley and the Salt River generally range between [illegible] and 1,[illegible] mg/L. Water along the Salt River is variable in quality, and dissolved-solids concentrations range from about [illegible] to 1,[illegible] mg/L. Water containing less than 1,[illegible] mg/L dissolved solids is present along the Salt River in a band from the east edge of the study area to within about [illegible] mi of the confluence with the Gila River. During an earlier study by Kister (1974), ground water beneath this part of the Salt River contained dissolved-solids concentrations of more than 1,[illegible] mg/L. The decrease in salinity in this area during the past decade probably was due to recharge from the Salt River. Higher-than-average runoff during several years in the last decade has resulted in the release of large quantities of water into the normally dry Salt River channel. As mentioned previously, between February [illegible] and June [illegible], estimated streamflow losses of at least [illegible] acre-ft occurred between Jointhead Dam near the east boundary of the study area and Gillespie Dam several miles southwest of the west edge of the study area (Mann and Rohne, [illegible]). Water in the Salt and Verde Rivers contained dissolved-solids concentrations from 100 to 900 mg/L during this time; concentrations ranged between about 200 and 500 mg/L during higher flows.

Vertical Variation in Water Quality

Water-quality variations with depth are significant but, on a basinwide scale, generally are not as large as areal variations within a unit. The variation of major ions and [illegible] percentage of coarse materials and yields water with a lower specific conductance than do the overlying sediments (see wells (A-1-2)9cbc2 and (A-1-2)17add). In the above examples, the specific conductance decreased by more than [illegible] microsiemens per centimeter from the [illegible] lower part of the lower unit. In areas where the lower part of the lower unit contains evaporite deposits, this decrease is not known to occur. In wells [illegible] and [illegible], the specific conductance increased with increasing depth from less than [illegible] to more than [illegible] and [illegible], respectively.

Water samples from city of [illegible] test well [illegible] were obtained from several discrete zones within the lower part of the lower unit. All four samples contained smaller dissolved-solids concentrations than water from a well located one-half mile to the south and perforated opposite the fine-grained sediments of the middle unit and upper part of the lower unit.

The largest observed increases in dissolved-solids concentrations with depth occur near the Luke salt body and are related to the presence of large amounts of halite, gypsum, and anhydrite in the lower unit. Within this area, the vertical and areal distribution of dissolved solids and specific conductance varies greatly. In Air Force test well (B-2-1)21ccb2, specific conductance increased from [illegible] at a depth of [illegible] ft to more than [illegible] at a depth of [illegible] ft below the land surface. Water from well [illegible] contained dissolved-solids concentrations of about [illegible] mg/L from a zone between [illegible] ft below the land surface and about [illegible] mg/L from a depth of [illegible] ft where geophysical logs indicate the presence of halite. In a well one-half mile to the west, where the top of the salt body is deeper, specific conductance ranged from [illegible] to [illegible] or from about [illegible] to [illegible] mg/L of dissolved solids between depths of [illegible] and [illegible] ft below the land surface.

Fluoride

The MCL (maximum contaminant level) of fluoride in public-supply water is 4.0 mg/L (U.S. Environmental Protection Agency, [illegible]). The State of Arizona, however, maintains a more stringent guideline under which the maximum contaminant level of fluoride in public-supply water in the study area is 1.4 mg/L, which is based on the average annual maximum daily air temperature ([illegible], [illegible]). Water containing more than 1.4 mg/L fluoride occurs in a large area in Buckeye Valley (fig. 14). The sources of fluoride in basin-fill deposits are acidic and intermediate volcanic rocks and the minerals hornblende and mica (Robertson, in press). In T. [illegible] N., R. [illegible] W., and T. [illegible] N., R. [illegible] W., fluoride values of more than 2 mg/L are almost always associated with wells perforated in the lower unit. The largest value in this area, [illegible] mg/L, was from a sample from well [illegible]. This well is perforated from [illegible] to [illegible] ft below the land surface and derives water from both the upper and lower parts of the lower unit. Most of the wells in adjacent sections are shallower and none yield water with a fluoride concentration of more than 2 mg/L. Water that exceeds the Arizona MCL is present north of Wittmann in sediments composed of granitic, volcanic, and schistose detritus of the Hieroglyphic Mountains. Fluoride concentrations throughout the rest of the study area do not exceed 1.4 mg/L.

Laney (1972) noted the association of large fluoride concentrations with high pH values in the Tucson basin as well as in other areas in southern Arizona. The average pH of more than 200 water samples in the western part of the Salt River Valley area was 7.57. In samples where fluoride

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ARIZONA DEPARTMENT OF WATER RESOURCES, SALT RIVER PROJECT, and
ARIZONA MUNICIPAL WATER USERS' ASSOCIATION

AQUIFER CHARACTERISTICS

The lower, middle, and upper units of the basin fill compose one aquifer in the study area. Aquifer characteristics—most importantly, hydraulic conductivity, transmissivity, and specific yield—quantify ground-water movement and storage in aquifers. The capability of the units to store and transmit water controls the rate at which ground water may be pumped from the aquifer.

Hydraulic Conductivity

Hydraulic conductivity is the volume of water at the existing kinematic viscosity that will move in a given time under a unit hydraulic head through a unit area at right angles to the direction of flow (Lohman and others, 1972). The hydraulic conductivity is a function of many factors, including particle-size distribution, consolidation, sorting, and nature of the pore spaces. Transmissivity is the hydraulic conductivity multiplied by the thickness of the aquifer.

Transmissivity values from more than 100 aquifer tests were used to obtain field values of hydraulic conductivity. In addition to the 23 tests done as part of this study, transmissivity values also were obtained from water-level recovery tests made on more than 60 wells in the study area (Nicholl and Long, 1981). Kenneth D. Schmidt and Associates (written commun., 1983) provided data from several tests. The average percentage of sand and gravel (particle size greater than 0.062 mm in diameter) at each location was determined from maps showing percent sand and gravel in each unit.

The depth of burial, which is defined in this report as the distance from the land surface to the midpoint of the saturated perforated interval of the well, was determined in order to explore the relations between depth of burial, average percent sand and gravel, and hydraulic conductivity (fig. 19). Because consolidation generally increases with depth, the average depth of burial may indirectly reflect the decrease in pore space caused by increasing overburden.

Lower Unit

Observed hydraulic-conductivity values in the lower part of the lower unit were from 6 to 9 ft/d in sediments ranging from 50 to 90 percent sand and gravel. Because few hydraulic-conductivity values were available from wells perforated in the lower part of the lower unit, a quantitative relation between hydraulic conductivity and particle size was not established. Some general conclusions, however, can be drawn from the data. In the lower part of the lower unit, hydraulic conductivity appears to be unrelated to grain size, at least where the unit contains more than 50 percent sand and gravel (fig. 19). The insensitivity of hydraulic conductivity to grain size indicates that other factors, such as degree of fracturing and cementation, may control permeability.

Observed hydraulic-conductivity values in the upper part of the lower unit were from 3 to 24 ft/d in sediments ranging from about 10 to 75 percent sand and gravel. The depth of burial ranged from 410 to 910 ft below the land surface. Plots of hydraulic conductivity and average percent sand and gravel for the upper part of the lower unit approximated a straight line on semi-log paper with hydraulic conductivity on the log scale, indicating that the relation is logarithmic (figs. 19, 20). Regression analysis of the common logarithm of hydraulic conductivity as a function of average percent sand and gravel yielded the prediction equation:

$$\log K \text{ (predicted)} = 0.011538 \text{ pct} + 0.22763.$$

The correlation coefficient for this regression was 0.86. The relation between hydraulic conductivity and percent sand and gravel is shown in figure 20. Regression analyses indicated that hydraulic conductivity was more dependent on average percent sand and gravel than on depth of burial. The depth of burial is a significant but secondary factor controlling permeability in the upper part of the lower unit. For points that plotted above the prediction curve (fig. 20), the average depth of burial was 713 ft below the land surface, and the average depth of burial for those that plotted below the curve was 816 ft below the land surface.

The available data indicate that the lower and upper parts of the lower unit have different water-bearing characteristics. For a given average percent sand and gravel, conductivity values for the lower part of the lower unit generally are lower than those for the upper part. In the lower part, ground-water flow rates are controlled by degree of fracturing and cementation; in the upper part, flow rates are controlled by particle size.

Middle Unit

Observed hydraulic-conductivity values for wells perforated in the middle unit were from 4 to 40 ft/d in sediments ranging from 28 to 62 percent sand and gravel over a range in depth of burial from 215 to 540 ft below the land surface. Regression of hydraulic conductivity as a function of average percent sand and gravel yielded a correlation coefficient of 0.11. Because of the small data set and low correlation coefficient obtained by statistical analysis, a quantitative relation was not established for the middle unit. Some general conclusions, however, can be drawn. The hydraulic characteristics of the middle unit, although not as well defined, are similar to those of the upper part of the lower unit. On a scatter diagram of hydraulic conductivity and average percent sand and gravel (fig. 19), data points for the middle unit plotted above and below those for the upper part of the lower unit, indicating the lack of a definite trend of higher or lower hydraulic-conductivity values for a given particle size.

The hydraulic conductivity is not well defined on the basis of average percent sand and gravel partly because the middle unit is heterogeneous. As previously stated, geophysical evidence indicates that the middle unit is characterized by interbeds of fine and coarse material. The factors limiting the movement of water may not be the average percent sand and gravel of a given depth interval, but rather the degree, extent, and bedding frequency of fine-grained deposits. Therefore, the average percent sand and gravel of the entire thickness at a given point may not always be a complete indicator of the hydraulic characteristics of the unit.

The relation between hydraulic conductivity and average percent sand and gravel was indefinite also because the latter varied little at wells where aquifer tests were available. All except two of the data points for the middle unit are between 30 and 50 percent sand and gravel. Hydraulic-conductivity values in areas where grain size in the middle unit is finer and coarser are needed to better define this relation.

Data for the middle unit indicate a trend of decreasing hydraulic conductivity with depth (fig. 19). As mentioned previously, depth of burial may indirectly reflect increases in compaction and (or) induration with depth. This relation is affected by other factors that may vary with depth, such as sorting (including the relative amounts of silt and clay in the mud fraction) and grain angularity. A better understanding of these factors is needed to fully explain the observed trend.

On the basis of available data, the middle unit in the western part of the valley is less permeable than that in the eastern part. Hydraulic conductivity in the middle unit in the eastern part ranged from 20 to 100 ft/d (Laney and Hahn, 1986); only 2 of 15 available hydraulic-conductivity values for the middle unit in the western part exceeded 10 ft/d.

Upper Unit

The upper unit is the most permeable deposit in the study area. Hydraulic-conductivity values ranged from 180 to 1,700 ft/d, much higher than any found in either the middle or lower units. The sediments ranged from 50 to more than 95 percent sand and gravel over a range in depth of burial between 95 and 180 ft below the land surface. A quantitative relation between hydraulic conductivity, percent sand and gravel, and depth of burial was not established for the upper unit owing to the small sample size and lack of any definite trends.

Transmissivity and Specific Yield

A transmissivity map of the upper part of the lower unit was constructed (fig. 21). The map showing percent sand and gravel in the upper part of the lower unit was converted to a hydraulic-conductivity map by applying the prediction equation to all data points and contour lines. The conductivity map then was overlain by a saturated thickness map, and values of transmissivity were determined by multiplying the thickness by hydraulic conductivity at each data point and contour intersection.

Transmissivity in the upper part of the lower unit ranges from zero where the unit is not present to greater than 7,000 ft²/d, and ranges between 1,500 and 5,000 ft²/d in a large part of the basin (fig. 21). Transmissivity exceeds 7,000 ft²/d west of the Agua Fria River in T. 1 N., R. 1 W., where the unit contains more than 40 percent sand and gravel and is more than 1,000 ft thick. Transmissivity is greater than 5,000 ft²/d in the central part of Buckeye Valley where the unit contains more than 80 percent sand and gravel and is from 250 to 500 ft thick. Transmissivity decreases near the basin margins and also in the center of the basin where the unit contains less than 20 percent sand and gravel.

The transmissivity map does not include Sun City and a large area to the northwest because there was no apparent break between the middle unit and the upper part of the lower unit. However, data from aquifer tests from wells perforated between the base of the upper part of the lower unit and the water table indicate that transmissivity in the area between Sun City and Surprise may exceed 10,000 ft²/d.

Transmissivity distributions for the other basin-fill units could not be mapped owing to the lack of data and (or) the absence of a definable relation between particle size and hydraulic conductivity. Estimates of the range in transmissivity for the units are shown in table 1.

The specific yield, which describes the water-storage characteristics of the aquifer, is defined as the ratio of the volume of water that the rock or soil, after being saturated, will yield by gravity drainage to the volume of rock or soil (Lohman and others, 1972). Reliable field estimates of specific yield are difficult to obtain in basin-fill deposits because of the lack of observation wells at potential aquifer-test sites and the difficulty in performing long-term tests that would account for delayed drainage of the material. During the data-collection phase of the study, two multiple-well aquifer tests were conducted along the Salt River using wells perforated in poorly sorted sand and gravel of the upper unit. Reasonable estimates of the short-term specific yield were determined in one of these tests. The other test was affected by flow in the Salt River. The specific yield in the first test was estimated by relating the volume of water pumped to the volume of the cone of depression (Ramsahoye and others, 1961). The calculated specific yield was 12 percent on the basis of drawdowns in an observation well 62 ft from the pumped well and 10 percent using drawdowns from a well 78 ft from the pumped well. These short-term specific-yield values do not account for delayed drainage and are less than the long-term specific yield. They may serve as minimum values of specific yield in these sediments.

Long and others (1982) used a digital model to derive specific-yield values for different types of aquifer materials in the Salt River Valley. The calibrated values ranged from 1 percent for clay and similar materials to 25 percent for deposits containing abundant sand and gravel. Quantitative information concerning the variation of specific yield with depth is lacking. Specific yields in the lower unit, however, probably are less than those for similar material in the middle or upper unit because of decreasing pore space and increasing cementation with depth.

WELL YIELDS

The distribution of well yields in the study area is dependent mainly on particle size and sorting, saturated thickness, degree of cementation of the basin fill, well-construction characteristics, and well losses. Maximum yields generally are achieved in wells perforated in more than one unit. In certain areas, however, wells perforated in multiple units may not be desirable because of water-quality considerations.

Wells perforated entirely in the lower part of the lower unit yield from 200 to 2,100 gal/min (table 1) and are limited for the most part to T. 1 N., Rs. 2 and 3 W., where the unit is coarse grained and is an important source of water. In the eastern part of the Salt River Valley area, available data indicate that the lower part yields from 5 to 100 gal/min to wells (Laney and Hahn, 1986) and is not an important source of water. Wells perforated in the volcanic intervals of the lower part of the lower unit may yield more than 2,000 gal/min of water to wells in T. 1 N., R. 2 E. The upper part of the lower unit yields between 400 and 1,700 gal/min to wells. Most of these wells are between the Agua Fria River and the White Tank Mountains in Tps. 2, 3, and 4 N. In the rest of the basin, large-capacity wells generally draw water from a combination of the upper unit, the middle unit, and the upper part of the lower unit.

Wells that derive water from only the middle unit are mainly in a small area northwest of Luke Air Force Base and the Glendale area in Tps. 2 and 3 N., where the saturated thickness may exceed 750 ft. These wells yield between 150 and 2,200 gal/min. In the rest of the study area, the unit is not a major water producer but is used in combination with underlying and overlying units. In contrast, the middle unit in the eastern part of the Salt River Valley area is a major source of water in much of the basin (Laney and Hahn, 1986).

Wells that derive water from only the upper unit are in Tps. 1 N. and 1 S., where the saturated thickness is more than 150 ft. Yields range from 1,500 to more than 5,500 gal/min. The largest yields occur in T. 1 N., R. 2 E., north of the Salt River. The saturated thickness in this area is between 200 and 300 ft and average percent sand and gravel is between 60 and 80 percent.

SPECIFIC CAPACITY

Specific capacity is defined as the rate of discharge of water from a well divided by the drawdown in the discharging well (Lohman and others, 1972). Specific capacity is a function of aquifer and well characteristics and duration of pumping. The largest specific capacities occur in wells perforated in the upper unit. In areas where the saturated thickness is large and the unit contains large percentages of sand and gravel, specific capacity may exceed 200 (gal/min)/ft. Specific capacities of wells that produce water from units other than the upper unit generally range between 20 and 100 (gal/min)/ft. Specific capacities in wells perforated in the upper part of the lower unit and the middle unit in areas where the units are fine grained may be less than 10 (gal/min)/ft. Specific capacities in wells perforated in the coarse-grained parts of the lower part of the lower unit may exceed 15 (gal/min)/ft.

Specific capacity may serve as an indicator of the transmissivity of the aquifer. Two previous studies have explored the relation between specific capacity and transmissivity in basin-fill materials in central Arizona. Anderson (1968) derived the relation $T = 267.4 \cdot SC$, where transmissivity (T) is expressed in ft²/d and specific capacity (SC) in (gal/min)/ft. Nicholl and Long (1981) used the relation $T = 263.6 \cdot SC^{[illegible]}$ on the basis of more than 170 short-term aquifer tests done throughout the Salt River Valley in 1979. The latter study used 12-hour drawdowns associated with the aquifer tests to compute specific capacity.

Because drawdowns increase through time, the relation between specific capacity and transmissivity is not a constant. An empirical formula was derived that used transmissivity values from aquifer tests conducted in the Salt River Valley in 1979 and specific-capacity values based on 1985 summer drawdowns and winter static levels (the regional water table was rising during the sample period, so static water levels in the winters preceding and following the summer measurements were averaged to negate the effects of a changing regional water table). The formula $292.5 \cdot SC^{[illegible]}$ was computed using a logarithmic function. For large specific-capacity values, this formula results in transmissivity values somewhat less than those determined in the 1979 study but close to those derived by Anderson (1968).

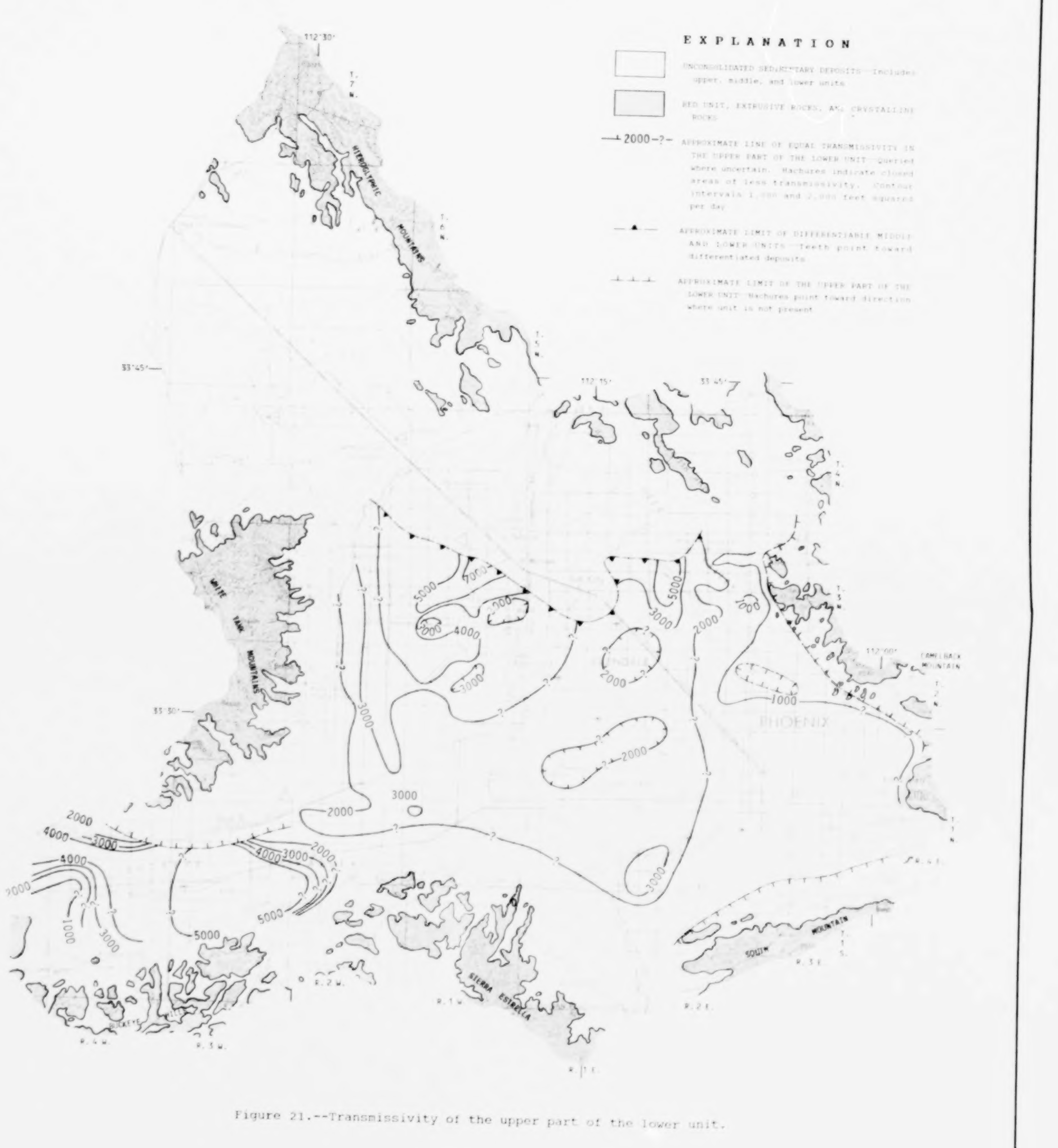
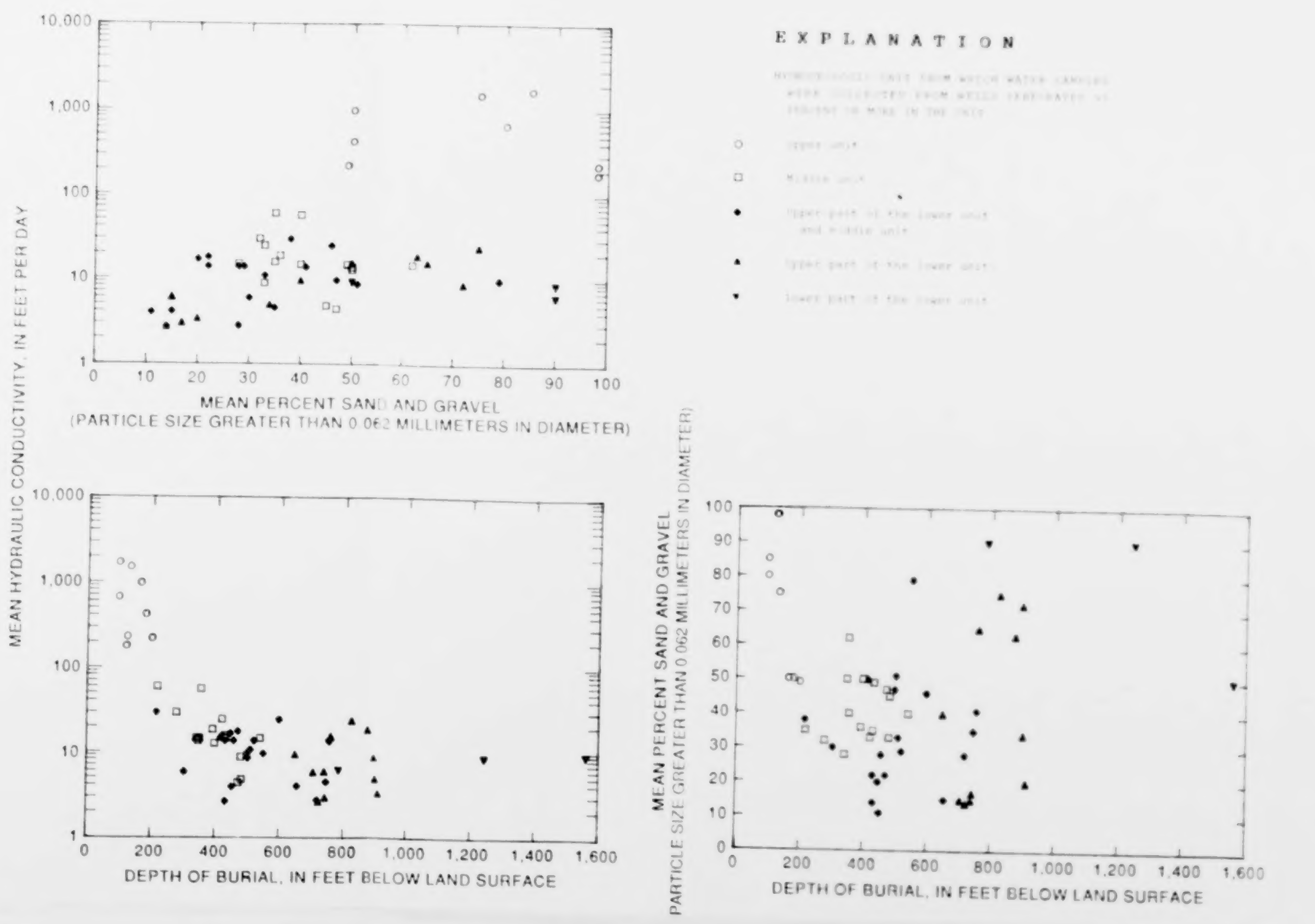

EXPLANATION
UNCONSOLIDATED SEDIMENTARY DEPOSITS—Includes upper, middle, and lower units
RED UNIT, EXTRUSIVE ROCKS, AND CRYSTALLINE ROCKS
2000—?—
APPROXIMATE LINE OF EQUAL TRANSMISSIVITY IN THE UPPER PART OF THE LOWER UNIT—Queried where uncertain. Hachures indicate closed areas of less transmissivity. Contour intervals 1,000 and 2,000 feet squared per day
APPROXIMATE LIMIT OF DIFFERENTIABLE MIDDLE AND LOWER UNITS—Teeth point toward differentiated deposits
APPROXIMATE LIMIT OF THE UPPER PART OF THE LOWER UNIT—Hachures point toward direction where unit is not present
112°30'
T. 7 N.
T. 6 N.
T. 5 N.
T. 4 N.
HIEROGLYPHIC MOUNTAINS
33°45'
112°15'
WHITE TANK MOUNTAINS
SIERRA ESTRELLA
PHOENIX
1000
2000
3000
4000
5000

Figure 21.--Transmissivity of the upper part of the lower unit.



SUMMARY

The study area can be divided into northeast and southwest regions on the basis of the structure of the crystalline rocks and the basin-fill units. The northeast region is dominated by several northwest-trending structural blocks and contains basin fill that generally is less than 2,000 ft thick. The southwest region is dominated by a large structural graben that forms the down-faulted core of the basin and contains basin fill that may be more than 10,000 ft thick. The structure of the basin-fill units has also been affected by movement of the Luke salt body, which may have displaced the lower unit several hundred feet.

The sedimentary deposits in the western part of the Salt River Valley area are divided into four units—the red unit, the lower unit, the middle unit, and the upper unit. The red unit consists mostly of reddish colored, well-cemented red beds that predate the period of high-angle faulting that formed the present-day sedimentary basins and mountain ranges. As a result, the sedimentary facies of the red unit are not related to present-day sedimentary basins and mountain ranges.

The lower unit is subdivided into lower and upper parts. The lower part consists of moderately cemented mudstone or siltstone that may be evaporitic; sand; gravel; conglomerate; and massive deposits of gypsum, anhydrite, and halite. The lower unit may be more than 10,000 ft thick in the graben where the deposits are largely fine grained. The lower part of the unit is coarse grained along the margins of the basin and may yield as much as 2,100 gal/min of water to wells. The upper part of the lower unit consists of weakly to moderately cemented clay, silt, mudstone, gypsiferous mudstone, gypsum, sand, and gravel and is fine grained throughout much of the study area. The upper part of the lower unit is locally absent and may exceed 1,500 ft in thickness in the graben.

The middle unit consists of weakly consolidated silt, sand, gravel, and clay and ranges in thickness from 100 to 800 ft. Where the unit is thickest, it may yield more than 2,000 gal/min of water to wells. Overdraft of the ground-water system has completely dewatered the middle unit west of Luke Air Force Base. The upper part of the lower unit and the middle unit are the main water-bearing units in the study area.

The upper unit consists mostly of unconsolidated silt, sand, and gravel. The unit is nearly 400 ft thick near the confluence of the Salt and Gila Rivers and is less than 200 ft thick toward the basin margins. The unit has been completely dewatered in the northern part of the study area. Where the saturated thickness is between 200 and 300 ft, the unit may yield more than 5,000 gal/min of water to wells.

The lower unit was deposited in a closed basin during the period of high-angle normal faulting. Similarly, the middle unit was deposited during closed basin conditions, although little or no faulting of the unit is evident. The upper unit was deposited after the development of integrated drainage. Facies distributions in the basin fill reflect the structural and the depositional conditions under which the units were deposited.

The units identified in the basin fill have different hydraulic characteristics. Estimated hydraulic conductivities in the lower part of the lower unit range from 6 to 9 ft/d and probably are controlled by the degree of cementation and fracturing. An empirical relation between hydraulic conductivity and grain size was developed for the upper part of the lower unit. Values of hydraulic conductivity ranged from 3 to 24 ft/d. Transmissivity values were estimated using maps of hydraulic conductivity and thickness. Transmissivity values range from 0 to 7,000 ft²/d and are between 1,500 and

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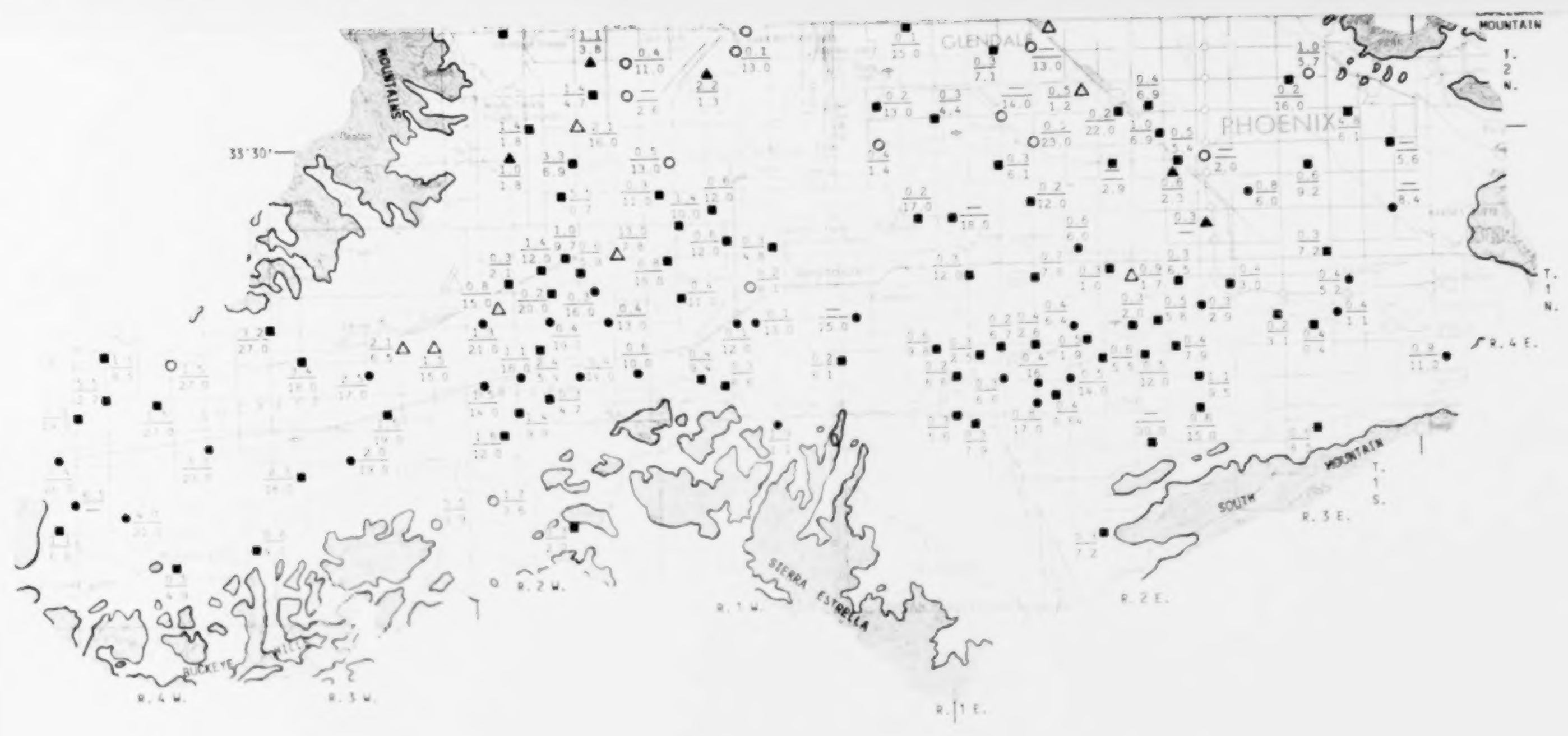


Figure 14.--Fluoride and nitrate concentrations in water from selected wells, 1980-85.

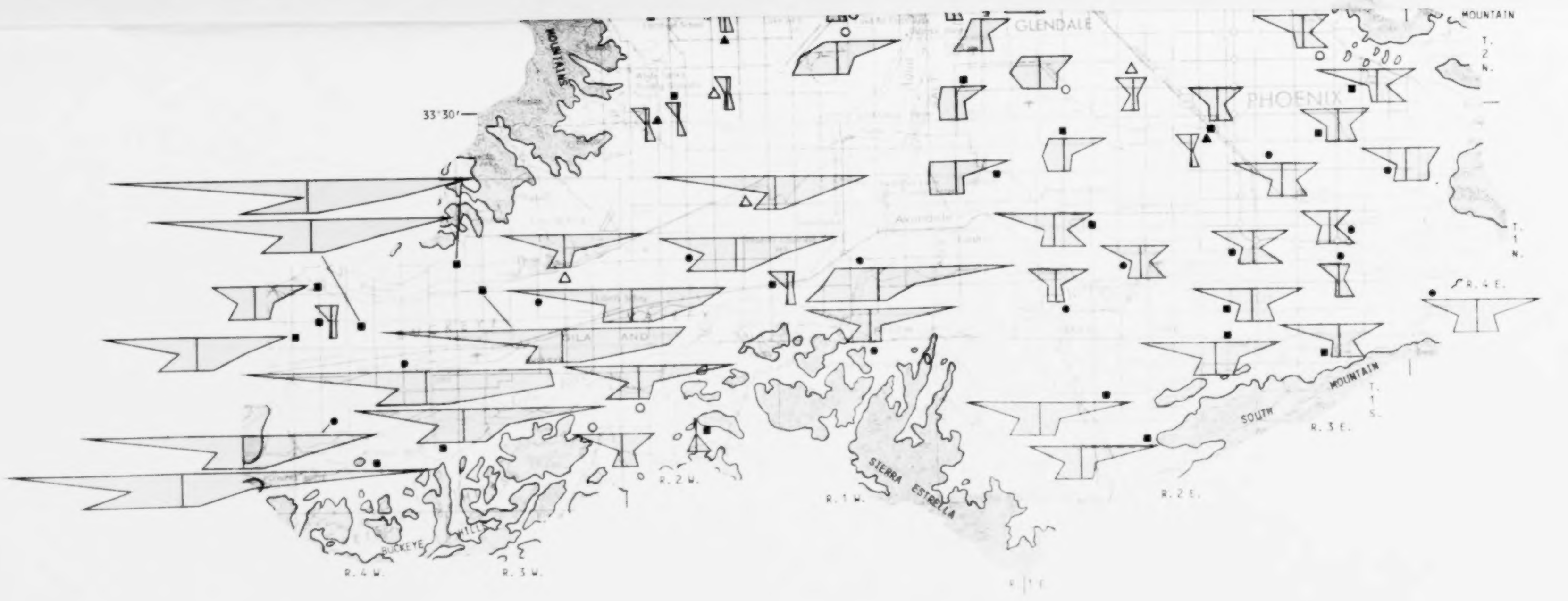
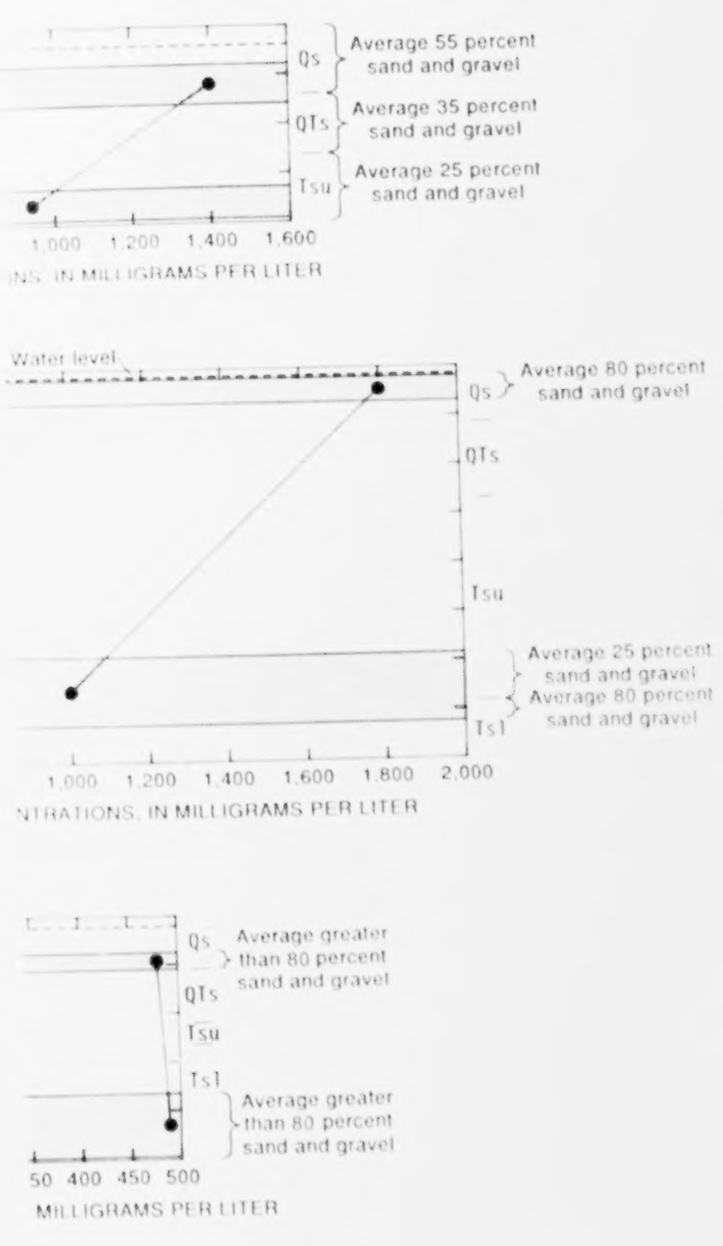


Figure 15.--Distribution of selected chemical constituents in water from selected wells, 1980-85.



ted wells

ams per

ns;

NITROGEN, NO2+NO3 DISSOLVED (mg/L as N)	SILICA, DISSOLVED (mg/L as SiO2)	CHROMIUM, HEXAVALENT, DISSOLVED (µg/L as Cr)	ARSENIC DISSOLVED (µg/L as As)	MANGANESE, DISSOLVED (µg/L as Mn)	SELENIUM DISSOLVED (µg/L as Se)	SPECIFIC CONDUCTANCE (µS/cm)	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (mg/L)
16.0	27	<1		<10		1,820	1,200
6.00	31	<1	3	580	2	2,410	1,400
1.00	21	2	5	2	<1	1,330	720
15.0	38	<1	6	<10	8	2,180	1,900
5.20	26	<1	6	<1	<1	1,440	850
11.0	37	<1	8	20	5	2,760	1,600
13.0	23	<1	2	3	2	1,440	760
--	--	--	--	--	--	1,080	--
2.30	21	31	5	1	<1	530	280
9.20	33	2	4	<1	5	1,600	1,000
11.0	31	<1	1	3	2	1,180	850
47.0							720
	30	33	6	2		720	--
4.60	34	<1		2		475	300
11.0	34	6	3	<1	1	850	340
4.50	42	1		8		438	270
7.10	26	8	4	<1	3	1,380	760
7.80	27	<1	74	<10	3	4,110	2,600
15.0	25	5	1	20	15	3,710	2,400
17.0	24	3	4	<10	18	4,750	3,100
27.0	35	<1	18	20	22	7,000	4,800
2.70	22	17	17	<1	3	540	320
5.80	28	<1	--	<3	--	880	470
7.20	19	3		2	--	1,550	850
1.80	25	<1		<2		715	380
3.80	21	2	10	<1	1	430	220
1.80	13	2	11	2	<1	380	210
6.50	25	15	9	<1	<1	670	370
2.00	20	49	25	<1	<1	425	260
5.40	20	33	5	<1	<1	610	320
0.540	23	55	34	<1	<1	400	210
1.20	27	<1	8	2	<1	528	310
0.750	17	3	1	4	<1	338	200
0.600	27	<1	1	3	<1	475	290
0.760	23	--		7	--	405	250
0.720	30	<1	7	12	--	1,390	980
3.20	34	<1	24	<3	--	575	360
1.10	32	4		3	--	660	410
1.10	30	<1	2	<10	<1	3,010	1,700
3.60	27	<1	1	<10	1	3,500	2,000
2.70	41	<1	--	<1	--	375	240
18.0	42	<1	6	<10	10	5,600	3,400
2.40	29	<1	6	<1	--	1,900	1,000
21.0	42	<1	12	<10	13	8,100	3,800
4.20	32	<1	3	10	1	5,050	3,100
3.20	35	<1	8	<10	3	3,650	2,100
3.20	27	10	3	6	--	3,070	1,700
0.50	25	<1	4	7	--	2,300	1,300

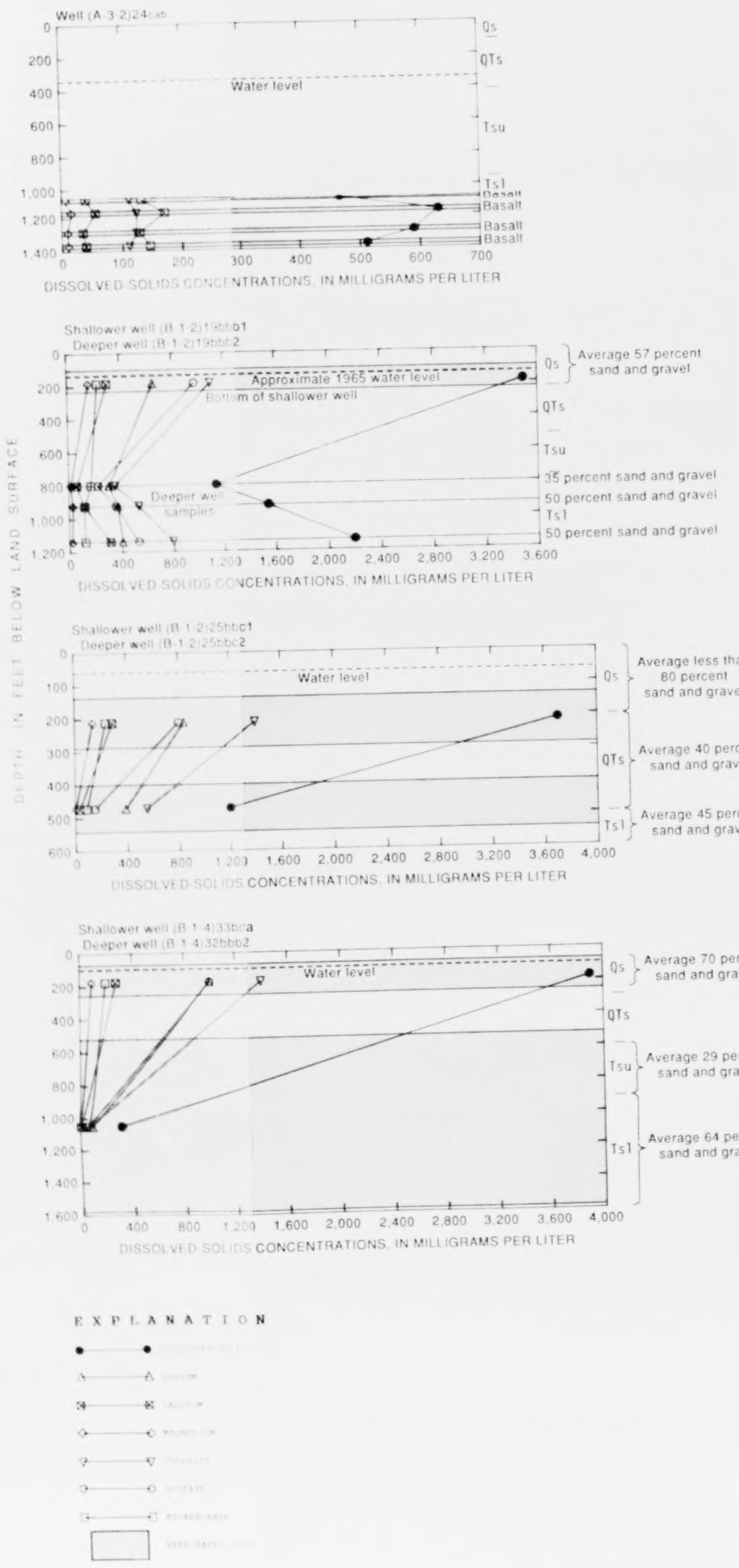


Figure 17.--Variation of selected dissolved constituents in ground water with depth.

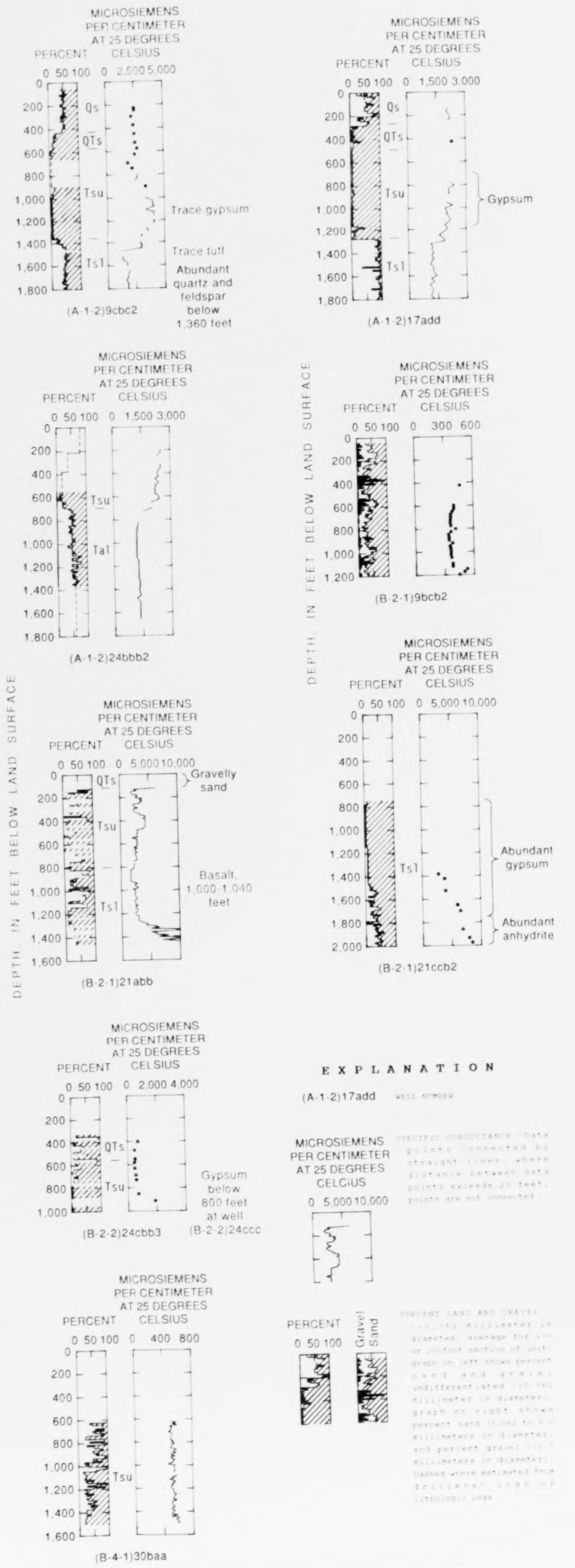


Figure 18.--Variation of specific conductance in ground water and particle size with depth.

Areal Distribution of Water Quality

Dissolved-solids concentrations in ground water range from 200 to greater than 4,500 mg/L (fig. 15) and may exceed 100,000 mg/L near the Luke salt body. Ground water containing less than 500 mg/L dissolved solids is found west and north of Luke Air Force Base. The major cations are sodium and calcium; the major anions are bicarbonate and chloride (fig. 15). Near Luke Air Force Base, dissolved-solids concentrations vary greatly and range from less than 1,000 mg/L to more than 100,000 mg/L. These extremely large concentrations are related to the presence of halite at the Luke salt body and associated evaporites. Water containing dissolved-solids concentrations of more than 1,000 mg/L occurs throughout Buckeye Valley and eastward to Avondale. In these areas, sodium and chloride are the dominant ions. Dissolved-solids concentrations exceeding 3,000 mg/L occur between Goodyear and Buckeye, although better-quality water may be found at depth in this area.

East of the Agua Fria River, water containing dissolved-solids concentrations of less than 500 mg/L occurs to the north of Sun City and in Deer Valley (fig. 15). The ground water in this area ranges from a mixed to mixed bicarbonate type. Bicarbonate is the dominant anion east of the Hedgpeth Hills. North of Sun City, concentrations of chloride and bicarbonate in milliequivalents per liter are approximately equal. In the southern part of Deer Valley, water containing dissolved-solids concentrations between 500 and 1,000 mg/L occurs in the brown mudstone of the upper part of the lower unit and in basalt flows and detritus at the lower part of the lower unit. The water is a mixed type but is somewhat anomalous in that magnesium concentrations in milliequivalents per liter are slightly higher than those of calcium or sodium. Magnesium in ground water is derived from ferromagnesian minerals, such as augite, hornblende, and biotite (Robertson, in press), all of which occur in varying amounts in the granitic and volcanic detritus in the basin fill. Montmorillonite is by far the most abundant clay mineral in basin-fill deposits (Robertson, in press) and also may be a source of magnesium.

Dissolved-solids concentrations in ground water between Deer Valley and the Salt River generally range between 300 and 1,400 mg/L. Water along the Salt River is variable in quality, and dissolved-solids concentrations range from about 450 to 1,600 mg/L. Water containing less than 1,000 mg/L dissolved solids is present along the Salt River in a band from the east edge of the study area to within about 5 mi of the confluence with the Gila River. During an earlier study by Kister (1974), ground water beneath this part of the Salt River contained dissolved-solids concentrations of more than 1,000 mg/L. The decrease in salinity in this area during the past decade probably was due to recharge from the Salt River. Higher-than-average runoff during several years in the past decade has resulted in the release of large quantities of water into the normally dry Salt River channel. As mentioned previously, between February 19[illegible] and June [illegible], estimated streamflow losses of at least [illegible] occurred between [illegible] Dam near the east boundary of the study area and Gillespie Dam several miles southwest of the west edge of the study area (Mann and Rohne, [illegible]). Water in the Salt and Verde Rivers contained dissolved-solids concentrations from 100 to 900 mg/L during this time; concentrations ranged between about 200 and 500 mg/L during runoff times.

Vertical Variation in Water Quality

Water-quality variations with depth are significant but, on a basinwide scale, generally are not as large as areal variations within a unit. The variations in major ions and dissolved solids with depth were examined using either data from adjacent wells drawing water from different depths or depth-specific samples from a single well (fig. 17). Water derived at least partially from the upper unit generally contained larger concentrations of dissolved solids than did water derived from either the middle or lower units. One exception is the pair of samples from wells in sections 21 and 22, T. 1 N., R. 3 E., in which the dissolved-solids concentrations were larger in the [illegible] than in the upper unit. This reversal of the more [illegible] of decreasing dissolved solids with depth, however, [illegible] a reflection of the previously mentioned influx of [illegible] water from the Salt and Agua Fria Rivers [illegible] concentrations of dissolved [illegible] most of the data indicated that upward or downward [illegible] in total dissolved solids were accompanied by similar [illegible] of the major ions. Regression analyses indicated [illegible] with the exception of bicarbonate and magnesium, [illegible] (correlation coefficients greater [illegible]) existed between dissolved solids and the major i[illegible]

The variation of specific conductance with depth in wells that were sampled during drilling is shown in figure 18. Specific conductance—the ability of water to conduct an electrical current—is a general indicator of the amount of dissolved solids in water. Regression analysis was used to examine the relation between specific conductance and dissolved solids in the ground water in the study area; the dissolved-solids concentration [illegible] of a ground-water sample can be estimated by multiplying the specific conductance in microsiemens [illegible] with an associated correlation [illegible]. Because good correlations exist between specific conductance and selected major ions (correlation coefficients greater than 0.83), the specific conductance [illegible] may serve also as qualitative indicators of the vertical trends in sodium, calcium, sulfate, and chloride.

In the absence of evaporite deposits, specific conductance of water in the middle unit and upper part of the lower unit in most of the basin [illegible] with depth (see fig. 18, wells (B-04-01)30ba[illegible]). The presence of evaporite deposits [illegible] generally is associated with an increase in specific conductance (see wells (A-01-02)09cbc2 and (B-02-02)24c[illegible]). [illegible] the basin, the lower part of the [illegible] having a higher percentage of coarse materials and yields water with a lower specific conductance than do the overlying sediments (see wells (A-01-02)17add and (A-01-02)24bbb2). In the above examples, the specific conductance decreased by more than 1,000 µS/cm (microsiemens per centimeter) from the upper to lower part of the lower unit. In areas where the lower part of the lower unit contains evaporite deposits, this decrease is not known to occur. In wells (B-02-01)21ccb2 and (B-02-01)21abb, the specific conductance increases with increasing depth from less than [illegible] to more than [illegible] and [illegible] µS/cm, respectively.

Water samples from City of Phoenix test well (A-03-02)24[illegible] were obtained from several basalt units interbedded within the lower part of the lower unit. All four samples contained smaller dissolved-solids concentrations than water from a well located one-half mile to the south and perforated opposite the fine-grained sediments of the middle unit and upper part of the lower unit.

The largest observed increases in dissolved-solids concentrations with depth occur near the Luke salt body and are related to the presence of large amounts of halite, gypsum, and anhydrite in the lower unit. Within this area, the vertical and areal distribution of dissolved solids and specific conductance varies greatly. In Air Force test well (B-02-01)21abb, specific conductance increased from [illegible] µS/cm at a depth of [illegible] ft to more than [illegible] µS/cm at a depth of [illegible] ft below the land surface. Water from well (B-02-01)20dd[illegible] contained dissolved-solids concentrations of about [illegible] mg/L from a zone between [illegible] ft below the land surface and about 144,000 mg/L from a depth of [illegible] ft where geophysical logs indicate the presence of halite. In a well one-[illegible] mile to the west, where the top of the salt body is deeper, specific conductance varied less, ranging from [illegible] to [illegible] µS/cm or from about [illegible] to [illegible] mg/L of dissolved solids between depths of [illegible] and [illegible] ft below the land surface.

Fluoride

The MCL (maximum contaminant level) of fluoride in public-supply water is [illegible] mg/L (U.S. Environmental Protection Agency, 1986). The State of Arizona, however, maintains a more stringent guideline under which the maximum contaminant level of fluoride in public-supply water in the study area is 1.4 mg/L, which is based on the average annual maximum daily air temperature (McClennan, 1984). Water containing more than 1.4 mg/L fluoride occurs in a large area in Buckeye Valley (fig. 14). The sources of fluoride in basin-fill deposits are acidic and intermediate volcanic rocks and the minerals hornblende and mica (Robertson, in press). In T. [illegible] N., R. [illegible] W., and T. [illegible] N., R. [illegible] W., fluoride values of more than 2 mg/L are almost always associated with wells perforated in the lower unit. The largest value in this area, [illegible] mg/L, was from a sample from well (B-0[illegible]). This well is perforated from [illegible] to [illegible] ft below the land surface and derives water from both the upper and lower parts of the lower unit. Most of the wells in adjacent sections are shallower and none yield water with a fluoride concentration of more than 2 mg/L. Water that exceeds the Arizona MCL is present north of Wittman in sediments composed of granitic, [illegible] and schistose detritus of the [illegible] Mountains. Fluoride concentrations throughout the rest of the study area do not exceed 1.4 mg/L.

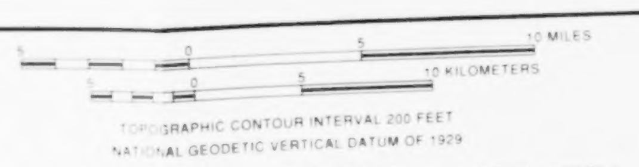
Carey ([illegible]) noted the association of large fluoride concentrations with high pH values in the Tucson basin as well as in other areas in southern Arizona. The average pH of more than 200 water samples in the western part of the Salt River Valley area was [illegible]. In samples where fluoride concentrations exceeded 1.4 mg/L, the average pH was [illegible]; samples containing more than [illegible] mg/L of fluoride had an average pH of [illegible].

Nitrate

The MCL of nitrate concentrations in public-supply water is 10 mg/L expressed as N for domestic supply (U.S. Environmental Protection Agency, [illegible]). Ingestion of water exceeding this limit has been shown to be harmful to infants. Water containing more than 10 mg/L of nitrate is present in several areas. The largest area extends from Buckeye Valley south of the Gila River and eastward to Goodyear (fig. 14). Although values exceeding the MCL are not limited to wells perforated in the upper unit, water that contains large concentrations of nitrate probably originates in or percolates to the upper unit and moves downward within the saturated zone as a result of pumping large amounts of water from the middle and lower units. Increases in nitrate concentrations through time were noted in this area and attributed to downward seepage of sewage releases (Maricopa Association of Governments, [illegible]). In addition, Wee ([illegible]) suggested that high nitrate values in this area may be caused by leaching of irrigated soils. Thirteen samples of ground water were available from wells perforated more than 50 percent in the upper unit, all of which yielded water containing nitrate concentrations of more than 10 mg/L. About half the samples from wells perforated less than 50 percent in the upper unit in Buckeye Valley contained nitrate concentrations of more than 10 mg/L.

A smaller area containing ground water with more than 10 mg/L of nitrate is present near the Salt River in T. 1 N., R. 2 E. The nitrates in this area probably originate from irrigation or sewage-return flows. Another area of large nitrate concentrations occurs in the upper part of the lower unit and the middle unit, from Glendale southeast to several miles north of the Salt River. The large concentrations of nitrates in this area probably have been in existence since the turn of the century (Maricopa Association of Governments, 1978), suggesting a natural or geologic origin. Several wells in the north half of T. 1 N., R. 1 E., produce water that contains large nitrate concentrations. The middle unit here is somewhat coarser than that to the north. These wells are perforated at least partially in the upper unit, however, and the source of nitrates may be related to human activities.

Geology modified from Cooley (1977)



TOPOGRAPHIC CONTOUR INTERVAL 200 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

HYDROGEOLOGY OF THE WESTERN PART OF THE SALT RIVER VALLEY AREA, MARICOPA COUNTY, ARIZONA

By James G. Brown and D. R. Pool
1989

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where the unit contains more than 50 percent sand and gravel (fig. 19). The insensitivity of hydraulic conductivity to grain size indicates that other factors, such as degree of fracturing and cementation, may control permeability.

Observed hydraulic-conductivity values in the upper part of the lower unit were from 3 to 24 ft/d in sediments ranging from about 10 to 75 percent sand and gravel. The depth of burial ranged from 410 to 910 ft below the land surface. Plots of hydraulic conductivity and average percent sand and gravel for the upper part of the lower unit approximated a straight line on semi-log paper with hydraulic conductivity on the log scale, indicating that the relation is logarithmic (figs. 19, 20). Regression analysis of the common logarithm of hydraulic conductivity as a function of average percent sand and gravel yielded the prediction equation:

$$\log K \text{ (predicted)} = 0.011575 \text{ pct} + 0.427622.$$

The correlation coefficient for this regression was 0.86. The relation between hydraulic conductivity and percent sand and gravel is shown in figure 20. Regression analyses indicated that hydraulic conductivity was more dependent on average percent sand and gravel than on depth of burial. The depth of burial is a significant but secondary factor controlling permeability in the upper part of the lower unit. For points that plotted above the prediction curve (fig. 20), the average depth of burial was 713 ft below the land surface, and the average depth of burial for those that plotted below the curve was 836 ft below the land surface.

The available data indicate that the lower and upper parts of the lower unit have different water-bearing characteristics. For a given average percent sand and gravel, conductivity values for the lower part of the lower unit generally are lower than those for the upper part. In the lower part, ground-water flow rates are controlled by degree of fracturing and cementation; in the upper part, flow rates are controlled by particle size.

Middle Unit

Observed hydraulic-conductivity values for wells perforated in the middle unit were from 4 to 60 ft/d in sediments ranging from 28 to 62 percent sand and gravel over a range in depth of burial from 210 to 540 ft below the land surface. Regression of hydraulic conductivity as a function of average percent sand and gravel yielded a correlation coefficient of 0.11. Because of the small data set and low correlation coefficient obtained by statistical analysis, a quantitative relation was not established for the middle unit. Some general conclusions, however, can be drawn. The hydraulic characteristics of the middle unit, although not as well defined, are similar to those of the upper part of the lower unit. On a scatter diagram of hydraulic conductivity and average percent sand and gravel (fig. 19), data points for the middle unit plotted above and below those for the upper part of the lower unit, indicating the lack of a definite trend of

Transmissivity and Specific Yield

A transmissivity map of the upper part of the lower unit was constructed (fig. 21). The map showing percent sand and gravel in the upper part of the lower unit was converted to a hydraulic-conductivity map by applying the prediction equation to all data points and contour lines. The conductivity map then was overlain by a saturated thickness map, and values of transmissivity were determined by multiplying the thickness by hydraulic conductivity at each data point and contour intersection.

Transmissivity in the upper part of the lower unit ranges from zero where the unit is not present to greater than 7,000 ft²/d, and ranges between 1,500 and 5,000 ft²/d in a large part of the basin (fig. 21). Transmissivity exceeds 7,000 ft²/d west of the Agua Fria River in T. 3 N., R. 1 W., where the unit contains more than 40 percent sand and gravel and is more than 1,000 ft thick. Transmissivity is greater than 5,000 ft²/d in the central part of Buckeye Valley where the unit contains more than 80 percent sand and gravel and is from 250 to 500 ft thick. Transmissivity decreases near the basin margins and also in the center of the basin where the unit contains less than 20 percent sand and gravel.

The transmissivity map does not include Sun City and a large area to the northwest because there was no apparent break between the middle unit and the upper part of the lower unit. However, data from aquifer tests from wells perforated between the base of the upper part of the lower unit and the water table indicate that transmissivity in the area between Sun City and Surprise may exceed 10,000 ft²/d.

Transmissivity distributions for the other basin-fill units could not be mapped owing to the lack of data and (or) the absence of a definable relation between particle size and hydraulic conductivity. Estimates of the range in transmissivity for the units are shown in table 1.

The specific yield, which describes the water-storage characteristics of the aquifer, is defined as the ratio of the volume of water that the rock or soil, after being saturated, will yield by gravity drainage to the volume of rock or soil (Lohman and others, 1972). Reliable field estimates of specific yield are difficult to obtain in basin-fill deposits because of the lack of observation wells at potential aquifer-test sites and the difficulty in performing long-term tests that would account for delayed drainage of the material. During the data-collection phase of the study, two multiple-well aquifer tests were conducted along the Salt River using wells perforated in poorly sorted sand and gravel of the upper unit. Reasonable estimates of the short-term specific yield were determined in one of these tests. The other test was affected by flow in the Salt River. The specific yield in the first test was estimated by relating the volume of water pumped to the volume of the cone of depression (Hammahoye and

not a major water producer but is used in combination with underlying and overlying units. In contrast, the middle unit in the eastern part of the Salt River Valley area is a major source of water in much of the basin (Laney and Hahn, 1986).

Wells that derive water from only the upper unit are in Tps. 1 N. and 1 S., where the saturated thickness is more than 150 ft. Yields range from 1,500 to more than 5,500 gal/min. The largest yields occur in T. 1 N., R. 2 E., north of the Salt River. The saturated thickness in this area is between 200 and 300 ft and average percent sand and gravel is between 60 and 80 percent.

SPECIFIC CAPACITY

Specific capacity is defined as the rate of discharge of water from a well divided by the drawdown in the discharging well (Lohman and others, 1972). Specific capacity is a function of aquifer and well characteristics and duration of pumping. The largest specific capacities occur in wells perforated in the upper unit. In areas where the saturated thickness is large and the unit contains large percentages of sand and gravel, specific capacity may exceed 250 (gal/min)/ft. Specific capacities of wells that produce water from units other than the upper unit generally range between 20 and 100 (gal/min)/ft. Specific capacities in wells perforated in the upper part of the lower unit and the middle unit in areas where the units are fine grained may be less than 10 (gal/min)/ft. Specific capacities in wells perforated in the coarse-grained parts of the lower part of the lower unit may exceed 15 (gal/min)/ft.

Specific capacity may serve as an indicator of the transmissivity of the aquifer. Two previous studies have explored the relation between specific capacity and transmissivity in basin-fill materials in central Arizona. Anderson (1968) derived the relation $T = 267.4 \cdot SC$, where transmissivity (T) is expressed in ft²/d and specific capacity (SC) in (gal/min)/ft. Niccoli and Long (1981) used the relation $T = 263.6 \cdot SC^{[illegible]}$ on the basis of more than 170 short-term aquifer tests done throughout the Salt River Valley in 1979. The latter study used 12-hour drawdowns associated with the aquifer tests to compute specific capacity.

Because drawdowns increase through time, the relation between specific capacity and transmissivity is not a constant. An empirical formula was derived that used transmissivity values from aquifer tests conducted in the Salt River Valley in 1979 and specific-capacity values based on 1980 summer drawdowns and winter static levels (the regional water table was rising during the sample period, so static water levels in the winters preceding and following the summer measurements were averaged to negate the effects of a changing regional water table). The formula $292.5 \cdot SC^{[illegible]}$ was computed using a logarithmic function. For large specific-capacity values, this formula results in transmissivity values somewhat less than those determined in the 1979 study but close to those derived by Anderson (1968).

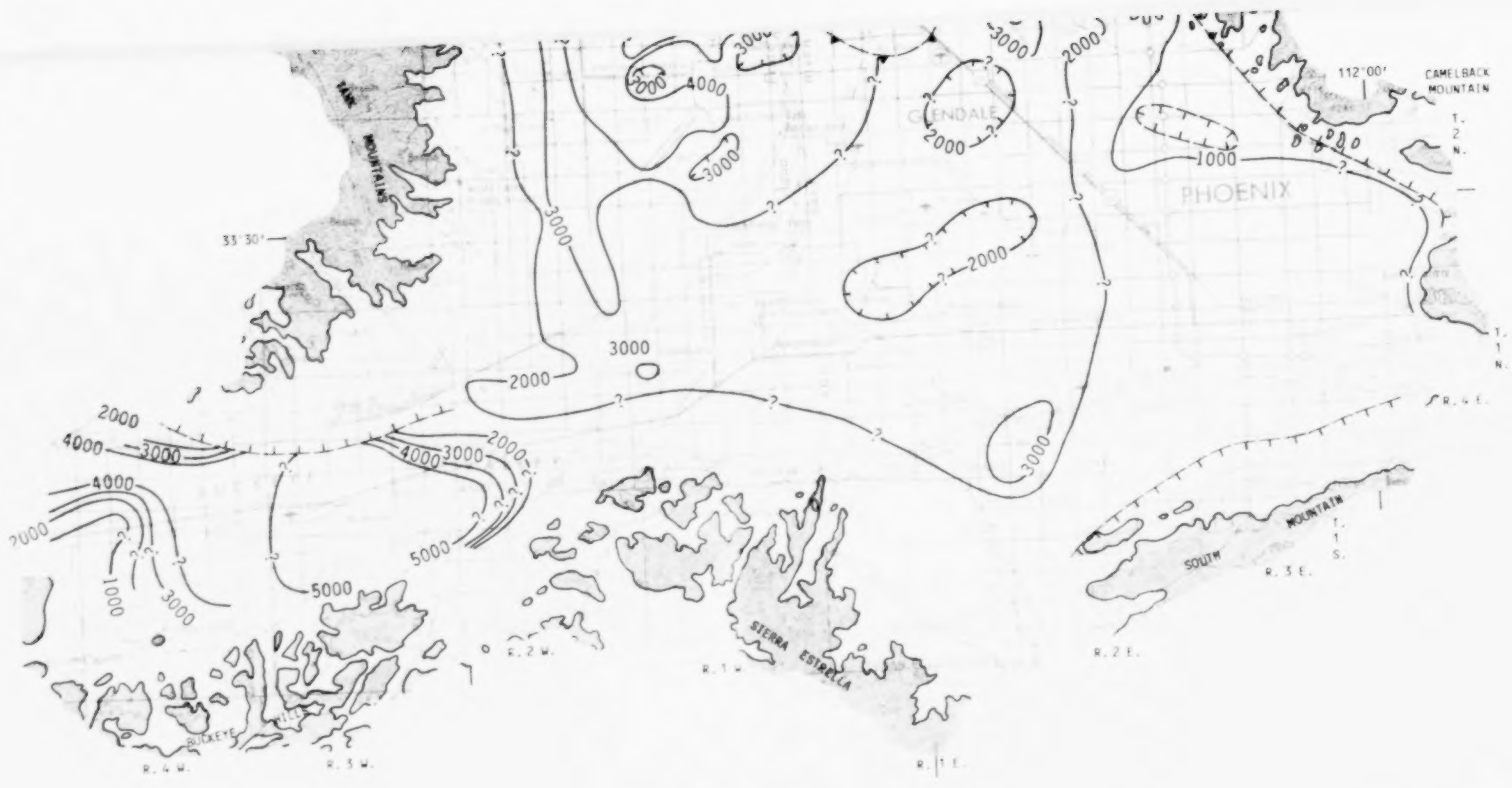

Figure 21.--Transmissivity of the upper part of the lower unit.

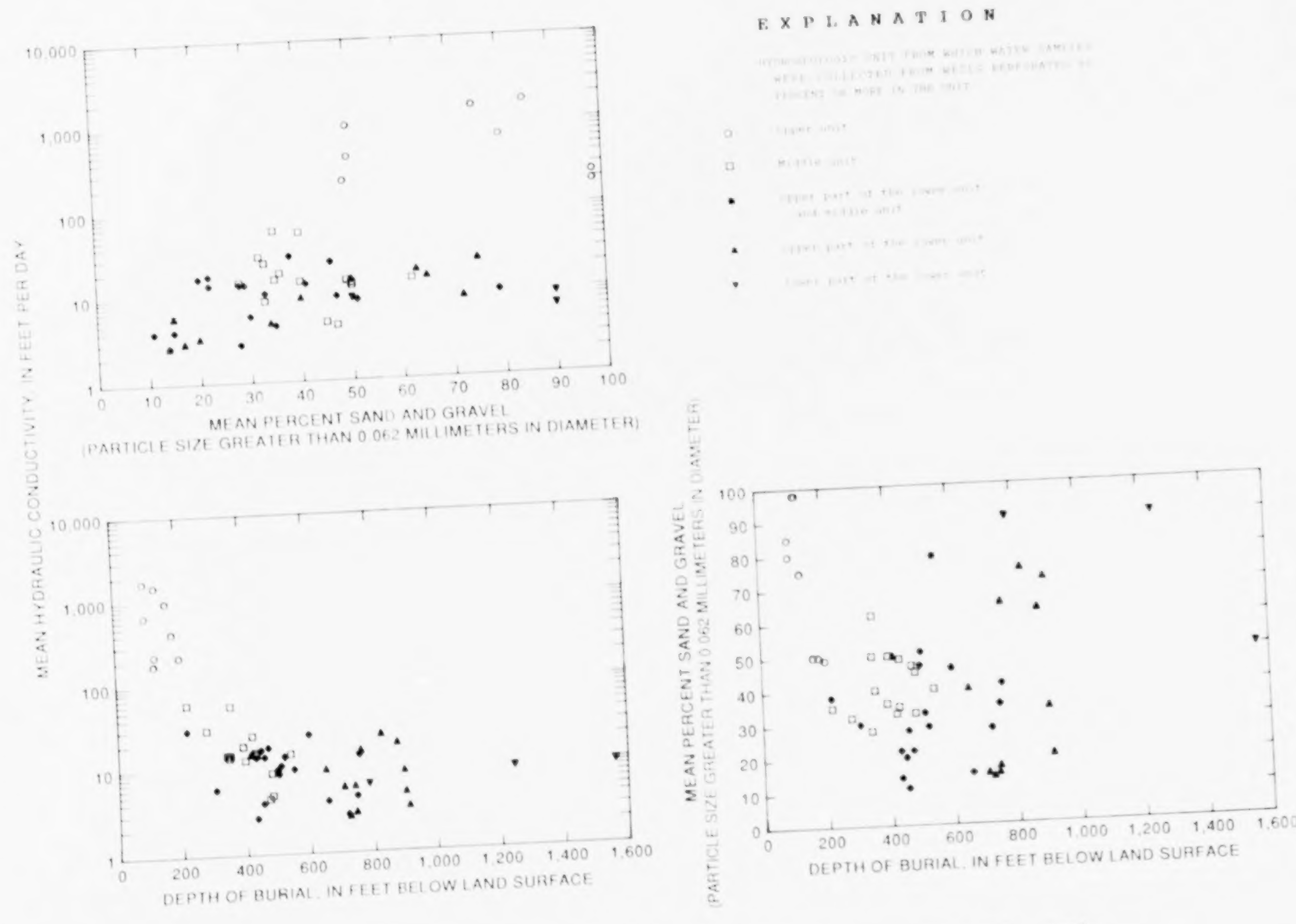

Figure 19.--Relation between hydraulic conductivity, percent sand and gravel, and depth of burial in the basin fill.

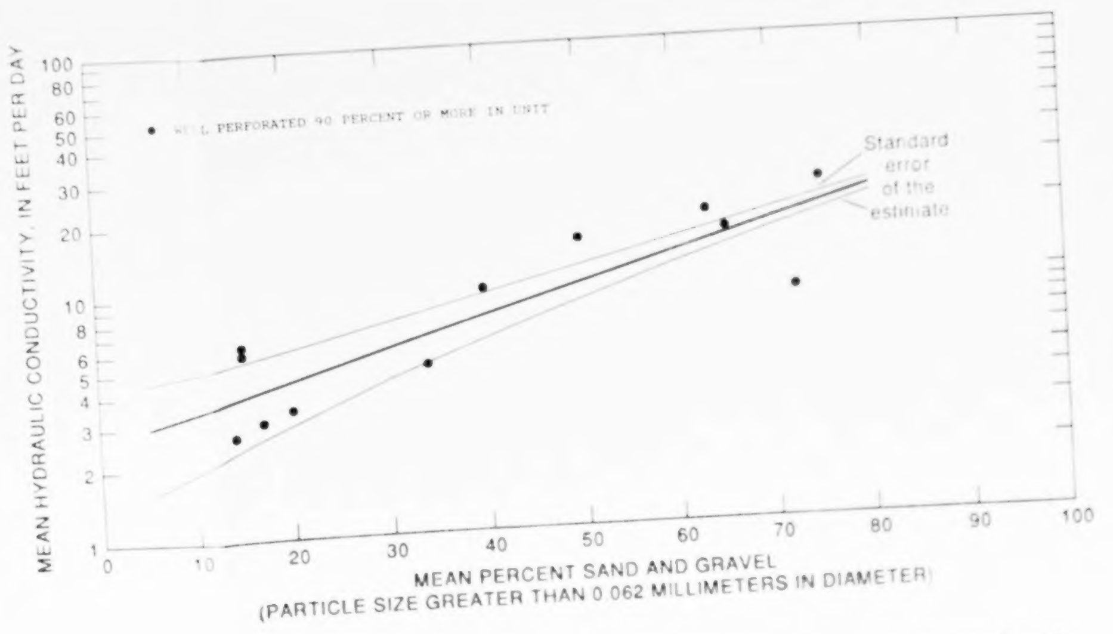

Figure 20.--Relation between hydraulic conductivity and percent sand and gravel in the upper part of the lower unit.

SUMMARY

The study area can be divided into northeast and southwest regions on the basis of the structure of the crystalline rocks and the basin-fill units. The northeast region is dominated by several northwest-trending structural blocks and contains basin fill that generally is less than 2,000 ft thick. The southwest region is dominated by a large structural graben that forms the down-faulted core of the basin and contains basin fill that may be more than 10,000 ft thick. The structure of the basin-fill units has also been affected by movement of the Luke salt body, which may have displaced the lower unit several hundred feet.

The sedimentary deposits in the western part of the Salt River Valley area are divided into four units--the red unit, the lower unit, the middle unit, and the upper unit. The red unit consists mostly of reddish colored, well-cemented red beds that predate the period of high-angle faulting that formed the present-day sedimentary basins and mountain ranges. As a result, the sedimentary facies of the red unit are not related to present-day sedimentary basins and mountain ranges.

The lower unit is subdivided into lower and upper parts. The lower part consists of moderately cemented mudstone or siltstone that may be evaporitic; sand; gravel; conglomerate; and massive deposits of gypsum, anhydrite, and halite. The lower unit may be more than 10,000 ft thick in the graben where the deposits are largely fine grained. The lower part of the unit is coarse grained along the margins of the basin and may yield as much as 2,100 gal/min of water to wells. The upper part of the lower unit consists of weakly to moderately cemented clay, silt, mudstone, gypsiferous mudstone, gypsum, sand, and gravel and is fine grained throughout much of the study area. The upper part of the lower unit is locally absent and may exceed 1,000 ft in thickness in the graben.

The middle unit consists of weakly consolidated silt, sand, gravel, and clay and ranges in thickness from 100 to 800 ft. Where the unit is thickest, it may yield more than 2,000 gal/min of water to wells. Overdraft of the ground-water system has completely dewatered the middle unit west of Luke Air Force Base. The upper part of the lower unit and the middle unit are the main water-bearing units in the study area.

The upper unit consists mostly of unconsolidated silt, sand, and gravel. The unit is nearly 400 ft thick near the confluence of the Salt and Gila Rivers and is less than 200 ft thick toward the basin margins. The unit has been completely dewatered in the northern part of the study area. Where the saturated thickness is between 200 and 300 ft, the unit may yield more than 5,000 gal/min of water to wells.

The lower unit was deposited in a closed basin during the period of high-angle normal faulting. Similarly, the middle unit was deposited during closed basin conditions, although little or no faulting of the unit is evident. The upper unit was deposited after the development of integrated drainage. Facies distributions in the basin fill reflect the structural and the depositional conditions under which the units were deposited.

The units identified in the basin fill have different hydraulic characteristics. Estimated hydraulic conductivities in the lower part of the lower unit range from 4 to 9 ft/d and probably are controlled by the degree of cementation and fracturing. An empirical relation between hydraulic conductivity and grain size was developed for the upper part of the lower unit. Values of hydraulic conductivity ranged from 3 to 24 ft/d. Transmissivity values were estimated using maps of hydraulic conductivity and thickness. Transmissivity values range from 0 to 7,000 ft²/d and are between 1,500 and 5,000 ft²/d over much of the basin. Hydraulic conductivity in the middle unit ranges from 4 to 60 ft/d and in the upper unit ranges from 180 to 1,700 ft/d. The relation between hydraulic conductivity and average percent sand and gravel was not quantified for either of these units.

The relation of specific capacity and transmissivity was determined using transmissivity values from aquifer tests done in 1979, specific-capacity values that were based on summer pumping levels and discharges, and winter static levels. The formula derived was similar to that of Anderson (1968).

Water quality in the study area ranges from good to poor. Dissolved-solids concentrations in the ground water range from 200 to more than 10,000 mg/L. Water quality is best in the northern part of the study area. Water containing over 4,500 mg/L of dissolved solids occurs in Buckeye Valley. Dissolved-solids concentrations tend to be greatest in the upper unit and decrease downward in the middle unit. Dissolved-solids concentrations in water in the middle unit and upper part of the lower unit generally are uniform with depth, except where concentrations increase in the presence of evaporite deposits. Large fluoride concentrations occur in the lower unit in Buckeye Valley and in detritus of the Hieroglyphic Mountains north of Wittmann. Large nitrate concentrations occur in the upper unit in Buckeye Valley and in the Glendale area in wells that draw water from the middle unit and upper part of the lower unit. Water moving through the ground-water system tends to increase in sodium, chloride, and dissolved solids.

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Geology modified from Cooley (1973)

Base from U.S. Geological Survey 1:250,000
Mesa, 1954-69 and
Phoenix, 1954-69

5 0 5 10 MILES
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TOPOGRAPHIC CONTOUR INTERVAL 200 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

HYDROGEOLOGY OF THE WESTERN PART OF THE SALT RIVER VALLEY AREA, MARICOPA COUNTY, ARIZONA

By James G. Brown and D. R. Pool
1989

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